[COMMITTEE PRINT]

UNITED STATES CIVILIAN SPACE PROGRAMS

VOLUME II

APPLICATIONS SATELLITES

REPORT

PREPARED FOR THE

SUBCOMMITTEE ON
SPACE SCIENCE AND APPLICATIONS
OF THE
COMMITTEE ON
SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
NINETY-EIGHTH CONGRESS
FIRST SESSION

BY THE
SCIENCE POLICY RESEARCH DIVISION
CONGRESSIONAL RESEARCH SERVICE
LIBRARY OF CONGRESS

Serial—M

MAY 1983

Printed for the use of the Committee on Science and Technology

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

U.S. GOVERNMENT PRINTING OFFICE
20-255 O WASHINGTON : 1983

H702-22

COMMITTEE ON SCIENCE AND TECHNOLOGY

DON FUQUA, Florida, *Chairman*

ROBERT A. ROE, New Jersey
GEORGE E. BROWN, Jr., California
JAMES H. SCHEUER, New York
RICHARD L. OTTINGER, New York
TOM HARKIN, Iowa
MARILYN LLOYD, Tennessee
DOUG WALGREN, Pennsylvania
DAN GLICKMAN, Kansas
ALBERT GORE, Jr., Tennessee
ROBERT A. YOUNG, Missouri
HAROLD L. VOLKMER, Missouri
BILL NELSON, Florida
STAN LUNDINE, New York
RALPH M. HALL, Texas
DAVE McCURDY, Oklahoma
MERVYN M. DYMALLY, California
PAUL SIMON, Illinois
NORMAN Y. MINETA, California
RICHARD J. DURBIN, Illinois
MICHAEL A. ANDREWS, Texas
BUDDY MacKAY, Florida
TIM VALENTINE, North Carolina
HARRY M. REID, Nevada
ROBERT G. TORRICELLI, New Jersey
FREDERICK C. BOUCHER, Virginia

LARRY WINN, Jr., Kansas
MANUEL LUJAN, Jr., New Mexico
ROBERT S. WALKER, Pennsylvania
WILLIAM CARNEY, New York
F. JAMES SENSENBRENNER, Jr., Wisconsin
JUDD GREGG, New Hampshire
RAYMOND J. McGRATH, New York
JOE SKEEN, New Mexico
CLAUDINE SCHNEIDER, Rhode Island
BILL LOWERY, California
ROD CHANDLER, Washington
HERBERT H. BATEMAN, Virginia
SHERWOOD L. BOEHLERT, New York
ALFRED A. McCANDLESS, California
TOM LEWIS, Florida

J. H. Poore, *Executive Director*
Robert C. Ketcham, *General Counsel*
Regina A. Davis, *Administrator*
David S. Jeffery, *Minority Staff Director*

Subcommittee on Space Science and Applications

HAROLD L. VOLKMER, Missouri, *Chairman*

BILL NELSON, Florida
MICHAEL A. ANDREWS, Texas
GEORGE E. BROWN, Jr., California
RALPH M. HALL, Texas
MERVYN M. DYMALLY, California
NORMAN Y. MINETA, California
BUDDY MacKAY, Florida
ROBERT G. TORRICELLI, New Jersey

MANUEL LUJAN, Jr., New Mexico
BILL LOWERY, California
ROD CHANDLER, Washington
HERBERT H. BATEMAN, Virginia
ROBERT S. WALKER, Pennsylvania

LETTER OF TRANSMITTAL

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C. May 1983.

Hon. DON FUQUA,
Chairman, Committee on Science and Technology

DEAR MR. CHAIRMAN: I am forwarding herewith the second and final volume of a study by the Science Policy Research Division, Congressional Research Service of the Library of Congress, entitled "United States Civilian Space Programs: Volume II—Applications Satellites." While an earlier part of the study which was published in December 1978 constituted an overview, the enclosed volume taken together with Volume I details the civilian space program of the United States and complements another report on World-Wide Space Activities prepared for our Committee by the Science Policy Research Division in 1977.

This report reviews what has been accomplished by the United States in the area of applications satellites since the inception of our space program. The document also identifies several significant issues for possible consideration by the Committee.

With this volume the study is completed. I feel that this work will have a continuing value to the Committee and to the government, university, and industrial community dealing with opportunities and issues of the space program.

Sincerely,

HAROLD L. VOLKMER,
Chairman, Subcommittee on Space Science and Applications.

LETTER OF SUBMITTAL

THE LIBRARY OF CONGRESS,
CONGRESSIONAL RESEARCH SERVICE,
Washington, D.C., March 16, 1983.

Hon. HAROLD L. VOLKMER,
Chairman, Subcommittee on Space Science and Applications, Committee on Science and Technology, House of Representatives, Washington, D.C.

DEAR MR. CHAIRMAN: The Congressional Research Service is happy to transmit to you the second volume of United States Civilian Space Programs, enclosed herewith. This completes the detailed history of the U.S. civilian space program which your subcommittee requested in 1978, volume I of which was published by your committee in January 1981. Volume II deals specifically with applications satellites—communications, meteorology, earth resources and environmental monitoring, ocean sensing, geodynamics, navigation, and tracking and data relay—and covers the time period 1958 through December 31, 1981. In cases where work was still in progress, portions of volume II are current through 1982.

The study was prepared by CRS specialists from the Science Policy Research Division, with contributions by two contractors and several student interns. Marcia S. Smith, Specialist in Aerospace and Telecommunications Systems, and Jane Bortnick, Specialist in Information Science and Technology, were responsible for portions of the texts and completion of the final document. Barbara A. Luxenberg and Lani H. Raleigh, two former CRS specialists, were responsible for initial phases of the study and made contributions to the text. In addition, some of the material in this report is updated from a chapter prepared by Ms. Raleigh in 1976 for a previous study for your committee "World-Wide Space Activities." Thomas K. McKnight of Orion Telecommunications and John (Tony) Reichhardt, consultants to CRS, contributed sections to the report under the direction of Ms. Bortnick and Ms. Smith. Additional support was provided by four CRS interns: Susan E. Crowe (University of Colorado), Dee Ann Divis (University of Nebraska), Scott Fennessey (Cornell University), and Jeryl Johnson (Howard University).

We hope that this comprehensive study of U.S. civilian applications satellites and the issues it identifies in chapter two will serve you and the members of your subcommittee in your continuing deliberations on NASA funding and the future of the space program.

Sincerely,

GILBERT GUDE, *Director.*

ABBREVIATED TABLE OF CONTENTS

Page

Letter of transmittal III
Letter of submittal V
Abbreviated table of contents VII
List of tables IX
List of figures XI
Expanded table of contents XIII
Acknowledgments XXV
Chapter One—Introduction and summary 1
Chapter Two—Issues for congressional consideration 3
  I. Issues concerning communications satellites 3
  II. Issues concerning civil land remote sensing satellites 6
  III. Remote sensing of the oceans from space 8
  IV. Issues concerning meteorological satellites 9
  V. Issues concerning navigation satellites for civil users 9
  VI. The tracking and data relay satellite system 10
Chapter Three—Communications satellites 11
  I. Introduction 11
  II. Communications Satellite Corp. [Comsat] 12
  III. International Telecommunications Satellite Organization [Intelsat] 28
  IV. Aeronautical communications satellites 53
  V. Maritime communications satellites 73
  VI. Public service communications satellite programs 92
  VII. Search and rescue satellite 108
  VIII. OSCAR 115
  IX. Domestic communications satellites 120
  X. Direct broadcast satellites 144
Chapter Four—Meteorological satellites 195
  I. Introduction 195
  II. TIROS 1 and organization of operational meteorological satellite structure 198
  III. U.S. meteorological satellites 199
  IV. Future meteorological satellites 209
  V. Participation of the United States in international meteorological programs 210
  VI. Value of meteorological satellites 213
Chapter Five—Earth resources and environmental monitoring satellites 219
  I. Landsat 219
  II. Applications explorer mission satellites for remote sensing and environmental observations 288
Chapter Six—Ocean sensing satellites 295
  I. Seasat 296
  II. National oceanic satellite system [NOSS] 305
  III. Future proposals 311
Chapter Seven—Geodynamic satellites 313
  I. Introduction 313
  II. Project Anna 317
  III. Explorer satellites with geodynamic missions 322
  IV. PAGEOS 323
  V. GEOS 3 324
  VI. LAGEOS 326
  VII. Proposals for future civilian geodynamic satellites 330
Chapter Eight—Navigation satellites 333
  I. Transit 337
  II. Technology improvement programs for navigation satellites 340
  III. NAVSTAR global positioning system 341

Page
Chapter Nine—Tracking and data relay satellite system 367
  I. Introduction 367
  II. System description 368
  III. Program history 372

LIST OF TABLES

Page
3-1 Inmarsat Members 83
3-2 Inmarsat Shore Stations, Existing and Planned 86
3-3 OSCAR Launch Summary 119
4-1 U.S. Meteorological Satellites, 1960-81 196
5-1 Landsat Spacecraft Characteristics 221
5-2 NASA Funding for the Landsat program 227
5-3 Users of Landsat Data: Fiscal Year 1977-81 230
5-4 NASA Funding History for the AGRISTARS Program 236
5-5 Summary of Possible Requirements for Land Remote Sensing 258
5-6 U.S. Agency for International Development Remote Sensing Program 268
5-7 International Participation in NASA's Earth Resources Investigations Programs 270
5-8 Equipment Components and Characteristics of On-board Information Complex of "Meteor-2" Vehicle 277
5-9 Main Characteristics of MSU-SA, MSU-VA Devices and "Fragment-2" System 278
6-1 User Organizations That Participated in the Development of Seasat 299
6-2 Case Studies of Utility of Seasat Data by Title and Participating Organizations 303
6-3 Interagency NOSS Measurement Requirements 306
7-1 NASA Geodynamic Satellite Launches 316
8-1 U.S. Navigaton Satellite Launches 335
8-2 Navstar Cost Estimates 344
8-3 Systems to be replaced by Navstar GPS in DOD 362
9-1 TDRSS Schedule 367

LIST OF FIGURES

Page
3-1 Overview of Intelsat Satellite Generations 33
3-2 Year-by-Year History of Intelsat Development 37
3-3 Comparison Between a Domsat and DBS Satellite 147
3-4 Typical DBS System 149
5-1 Comparison of Scanning Systems for Earth Observations 261
5-2 Tradeoff: TM/Scanner VS. MLA/Pushbroom 262
8-1 Civil Applications 353
8-2 Typical Military Applications 354
8-3 Nav. System Comparisons 356
8-4 Nav. System Comparisons (continued) 357
8-5 Military Navigation System Comparison 358
8-6 Military Navigation System Comparison (continued) 359
9-1 Tracking and Data Relay Satellite System 369
9-2 Tracking and Data Relay Satellite (TDRS) 371

CONTENTS

CHAPTER ONE: INTRODUCTION AND SUMMARY

CHAPTER TWO: ISSUES FOR CONGRESSIONAL CONSIDERATION

Page

I. Issues Concerning Communications Satellites 3
  A. Government Versus Private Sector Roles 3
  B. Promotion of Competition 4
  C. International Cooperation 5
II. Issues Concerning Civil Land Remote Sensing Satellites 6
  A. Transfer of Landsat to the Private Sector 6
  B. Future of the U.S. Civil Land Remote Sensing Program 6
  C. Coordination with the Department of Defense 7
  D. International Issues 7
III. Remote Sensing of the Oceans from Space 8
IV. Issues Concerning Meteorological Satellites 9
  A. Number of U.S. Polar-Orbiting Meteorological Satellites 9
  B. Operation of Meteorological Satellites by the Private Sector 9
V. Issues Concerning Navigation Satellites for Civil Users 9
  A. Civil Access to NAVSTAR in Times of Crisis 9
  B. Charging Fees for Access to NAVSTAR 10
VI. The Tracking and Data Relay Satellite System 10

CHAPTER THREE: COMMUNICATIONS SATELLITES

I. Introduction 11
II. Communications Satellite Corporation [Comsat] 12
  A. Introduction 12
  B. The Communications Satellite Act of 1962 and the Origins of Comsat 13
    1. Policy Development in the Executive Branch 14
    2. The Congressional Process 17
  C. Comsat in Operation 19
    1. Cable versus Satellite in the Domestic Satellite Decision 19
    2. Current Structure of Comsat 22
      a. Intelsat Services 23
      b. Inmarsat Services 23
      c. Research and Development 24
      d. Comstar and Marisat Services 24
      e. Satellite Television Corp. [STC] 25
      f. Manufacturing 25
      g. Integrated Design and Manufacturing Systems 25
      h. Environmental Information Services 25
      i. Satellite Business Systems 25
    3. Furture Directions: The FCC Comsat Study 26
  D. Issues 28
III. International Telecommunications Satellite Organization [Intelsat] 28
  A. Organizational History and Evolution 29
    1. Communications Satellite Act of 1962 29
    2. Formation of Intelsat 29
    3. Interim Agreements 29
    4. Definitive Agreements 30
  B. Technology 31
    1. Spacecraft 31

Page
2. Earth Stations ... 35
C. Operation and Economics ... 36
1. Technological Evolution and System Expansion ... 36
2. System Reliability ... 38
3. System Economics ... 38
D. Early Policy Issues ... 39
1. Formation of Policy ... 39
2. Evaluation of Initial U.S. Policy ... 40
E. Current Policy Issues ... 41
1. Formulation of U.S. Policy ... 41
2. Recent Policy Developments ... 42
3. Promotion of Competition ... 44
a. Competing Satellite Systems ... 45
b. Intermodal Competition ... 47
c. Direct Access to Intelsat Space Segment ... 47
d. Earth Station Ownership ... 48
4. International Resale of Telecommunications Circuits ... 50
5. Foreign Policy Considerations ... 52
F. Conclusion ... 52
IV. Aeronautical Communications Satellite (AEROSAT) ... 53
A. Introduction ... 53
B. History ... 53
1. Early History ... 53
2. Comsat Proposal ... 55
3. ICAO Opposition to Comsat Plan ... 55
4. Modified Comsat Proposal To Comply With ICAO Recommendations ... 56
5. ICAO Rejection of Comsat Proposal ... 57
6. NASA/ESRO Proposal for L-Band Atlantic System ... 57
7. Airline Opposition ... 57
8. FAA Proposal—Hybrid System ... 58
9. Nixon Administration Policy—Unilateral L-Band Pacific Satellite ... 59
a. Negative Airline Reaction ... 59
b. European Reaction ... 60
10. FAA/ESRO Proposal ... 60
a. Negative Reaction—Industry ... 60
b. Congressional Reaction ... 60
11. Nixon Administration Rejection of FAA/ESRO Plan ... 61
12. European Reaction ... 61
13. Alternative Proposals ... 62
a. Comsat ... 62
b. ATA ... 62
c. ICAO ... 62
14. Revised Nixon Administration Policy ... 63
15. Airline Opposition to Nixon Policy ... 63
16. ATA Proposal ... 64
17. Congress Deletes Aerosat Funds ... 64
18. Congress Restores Aerosat Funds ... 65
19. FAA, Airlines Negotiate A Compromise Agreement ... 65
20. Renewed FAA/ESRO Negotiations ... 65
a. ESRO Modification of Technical Requirements ... 65
b. NASA Devises New Launcher Policy ... 66
21. Memorandum of Understanding ... 66
22. Program Termination ... 66
a. Denial of Fiscal Year 1976 Funds by Congress ... 66
b. Comsat Dispute ... 67
c. Congressional Opposition ... 67
C. Aerosat System Description ... 68
1. Overall Aerosat System ... 68
a. Space Segment Program ... 69
b. Coordinated Program ... 69
2. Space Segment ... 69
3. Ground Segment ... 69
4. Airborne Segment ... 70
D. Organizational Structure/Institutional Arrangements ... 70

Page
E. Policy Issues 71
1. Technological Advance Versus User Requirements 71
2. Institutional Organization 71
3. Foreign Relations 72
a. Foreign Cooperation versus Technical Expediency 72
b. International Agreements 72
4. Technical Obsolescence 73
5. Summary 73
V. Maritime Communications Satellites 73
A. Introduction 73
B. Marisat 74
1. History 75
2. Spacecraft Technology 76
3. Earth Terminals 76
4. Ship Terminals 76
5. Marisat System Coverage 77
6. Marisat System Costs and Ownership 77
7. Marisat System Services and Costs to Users 77
C. International Maritime Organization [Inmarsat] 78
1. 1975 Conference To Establish Inmarsat 78
a. Background 78
b. Areas of Controversy 79
2. February 1976 London Conference—Unresolved Differences 80
a. Designated Entities, Shareholding, and Voting Rights 80
b. Voting and Representation 81
3. Inmarsat Convention Opened for Signature 81
a. Administrative Provisions 81
b. Voting and Representation 81
4. Proposed Interim Arrangements 84
a. Joint Venture 84
b. Comsat 84
c. Pre-Inmarsat Agreement 84
5. Establishment of Operational Inmarsat 84
a. Space Segment 85
b. User Segment 85
c. Ground Segment 85
d. Services 87
6. U.S. Involvement in Inmarsat 87
a. Need for Legislation 87
b. Administration Views on Participation in Inmarsat 88
c. Congressional Views 88
Carrier's Carrier 89
Participating Carrier 90
Earth Station Ownership 91
d. Inmarsat Legislation Enacted 91
e. Federal Communications Commission Action 91
7. Next Generation Maritime Satellites 92
VI. Public Service Communications Satellite Programs 92
A. Introduction 92
B. ATS-1 and ATS-3 93
1. (ATS-1) Peacesat 94
2. ATS-3 94
C. Applications Technology Satellite—6 [ATS-6] 94
1. Introduction 94
2. Technology 95
3. SITE—Joint United States-India Experiment in Educational Broadcasting 95
a. The Program 96
b. The Results 96
Technical Aspects 97
Project Management and Institutional Framework 97
The Indian Context 97
4. AIDSAT—Joint AID/NASA Satellite Communications Demonstration Project 98
5. ATS—6 Mission Costs 99
D. Communications Technology Satellite [CTS] 99
1. Introduction 99

Page
2. Technology 100
3. United States-Canadian Cooperation 101
4. Experiments 101
Education 101
Health Care 102
Community and Special Services 102
5. Cost 102
6. Program Termination 102
E. U.S. Policy for Public Service Communication Programs Following ATS-6 and CTS 103
1. Policy Review 103
2. NTIA Role 103
3. NASA Role 104
F. Public Service Satellite Consortium [PSSC] 104
1. Origin 104
2. Bridging the Gap Between Experimental and Operational 105
3. PSSC Services 106
4. Technical Facilities 106
a. Denver Satellite Access Facility 107
b. Transportable Earth Station [TES] 107
c. National Satellite Network [NSN] 107
d. Ku-band Earth Station Network 107
e. For-profit Subsidiary 108
G. Appalachian Community Service Network [ACSN] 108
VII. Search and Rescue Satellite 108
A. The Search and Rescue Satellite [Sarsat] Project 108
1. Project Background and Rationale 108
2. Technical Description and Sarsat Management 111
B. International Participation in the Cospas-Sarsat Project 113
1. The Sarsat Partnership 113
2. Soviet Involvement in Cospas-Sarsat 114
VIII. Orbiting Satellite Carrying Amateur Radio [OSCAR] 115
A. History 116
B. Phase I Satellites 116
C. Phase II Satellites and Amsat 117
D. OSCAR 9—UOSAT 117
E. Phase III Satellites 117
F. Experiments with OSCAR 120
IX. Domestic Communications Satellites 120
A. Introduction 120
B. A Brief History of Early Satellite Communications 121
1. The Moon 121
2. SCORE 121
3. Echo 122
4. Courier 122
5. Telstar 122
6. Syncom and the Geosynchronous Communications Satellites 122
C. A Brief History of Satellite Communications Policymaking 123
1. FCC Docket 16495 123
2. Deregulation of Domestic Receive-only Antenna Facilities 126
3. Orbital Positions and International Communications Policy 127
4. Deregulation of Communications Common Carriers 128
D. The Domestic Communications Satellite Fleet 130
1. Western Union 130
2. RCA American Communications, Inc 132
3. Comsat General Corp 135
4. Satellite Business Systems 136
5. American Telephone and Telegraph Co 137
6. GTE Satellite Corp 137
7. Hughes Communications Inc 138
8. Southern Pacific Communications Co. (SPCC) 139
9. American Satellite Corp 139
10. United States Satellite Systems Inc 139
E. Issues 140
1. Orbital Arcs and the Number of Communicating Spacecraft 140
2. Ariane 140

Page
3. Research and Development by NASA into Uses of Ka Band 140
4. Spacecraft Ownership 140
5. Copyright 141
6. Access 141
7. International 142
8. Theft of Service and Privacy Protection 142
9. International Destruction of Satellites 142
10. Cross-Subsidization 142
11. Transponder Glut 142
12. Ownership 143
13. Anticompetitive Conduct 143
14. Environmental Protection 143
15. Land-mobile Satellite Service 144
F. Conclusion 144
X. Direct Broadcast Satellites [DBS] 144
A. Introduction 144
1. Early History 145
2. The Technology 146
B. Federal Communications Commission [FCC] Actions 150
1. Staff Reports 150
2. Relevant FCC Dockets 150
3. DBS Applications 152
C. International Activities 156
1. DBS Efforts in Other Nations 156
2. U.N. Consideration of DBS 157
3. International Telecommunications Union [ITU] Consideration of DBS 158
D. Selected Issues 160
1. 1983 Regional Administrative Radio Conference [RARC–83] 160
2. Economic Viability 161
3. Displacement of Current Users of the 12 GHz Band 162
4. Effect on Existing Broadcasting Services 163
5. Government Regulation 164
6. High Definition Television [HDTV] 164
E. Congressional Interest 165
1. Congressional Hearings and Reports 165
2. WARC–79 Treaty Ratification 166
3. Congressional Role 167

APPENDICES, CHAPTER III

Appendix A. Memorandum on Legal Issues, 22 F.C.C. 2d 86, 128 (1970) 168
Appendix B. History of F.C.C. Docket 16495, 22 F.C.C. 2d 86, 108 (1970) 174
Appendix C. Flanigan Memorandum, 22 F.C.C. 2d 86, 125 (1970) 191

CHAPTER FOUR: METEOROLOGICAL SATELLITES

I. Introduction 195
II. TIROS 1 and Organization of Operational Meteorological Satellite Structure 198
III. U.S. Meteorological Satellites 199
A. Polar-Orbiting Satellites 199
1. TIROS 199
2. Nimbus 201
3. TOS/ESSA 203
4. ITOS/NOAA 1–5 204
5. TIROS N/NOAA 6–7 205
B. Geostationary Satellites 206
1. ATS 206
2. SMS/GOES 207
C. Existing Operational Meteorological Satellite System 208
IV. Future Meteorological Satellites 209
V. Participation of the United States in International Meteorological Programs 210
A. Equipment and Training 210
B. World Weather Program 211

Page
    1. World Weather Watch (WWW) 211
        a. Global Observing System (GOS) 211
        b. Global Data Processing System (GDPS) 212
        c. Global Telecommunications System (GTS) 212
    2. Global Atmospheric Research (GARP) 212
VI. Value of Meteorological Satellites 213

CHAPTER FIVE: EARTH RESOURCES AND ENVIRONMENTAL MONITORING SATELLITES

I. Landsat 219
  A. Introduction 219
  B. The Landsat Program 220
    1. The Spacecraft 220
    2. Landsats 1-3 222
      a. Return Beam Vidicon Subsystem 222
      b. Multispectral Scanners 222
      c. Data Collection System 223
      d. Spacecraft Status 223
    3. Landsat D and D' 224
    4. Program Costs 226
  C. Using Landsat Data 228
    1. Advantages of Remote Sensing Data from Satellites 228
    2. Users of Landsat Data 228
    3. Availability and Cost of Landsat Data 230
    4. U.S. Government Programs for Demonstrating Utility of Landsat Data 231
      a. Large Area Crop Inventory Experiment (LACIE) 231
      b. Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing (AgRISTARS) 233
      c. Geological Applications Program 236
  D. Making the Landsat Program Operational 237
    1. Summary 237
    2. Early Options 238
    3. President Carter's Directives: Transferring Landsat to NOAA 238
      a. PD-37 and PD-42 239
      b. PD-54—Designating NOAA to Take Control of the Landsat System 240
      c. Implementation of PD-54 241
    4. Congressional Efforts to Establish an Operational Landsat System 242
      a. 93rd Congress (1973-74) 242
      b. 94th Congress (1975-76) 244
        (1) S. 3759 244
        (2) 1976 GAO Report 245
      c. 95th Congress (1977-78) 246
        (1) S. 657 246
        (2) 1977 GAO Report 247
        (3) 1977 House Science and Technology Committee Hearings 247
        (4) 1978 GAO Report 248
        (5) S. 3589 248
        (6) S. 3625 249
        (7) Space Policy Legislation: S. 3530 and S. 3599 250
      d. 96th Congress (1979-1980) 250
        (1) Space Policy Legislation in the Senate: S. 212 and S. 244 250
        (2) 1979 House Science and Technology Committee Hearings on Space Policy 251
        (3) S. 663 and S. 875 251
        (4) 1979 and 1980 House Science and Technology Committee Hearings on Operational Civil Remote Sensing Systems 251
        (5) Space Policy Legislation in the House: H.R. 4316 and H.R. 6304 253
        (6) S. 3169 254
      e. 97th Congress, 1st session (1981) 254
        (1) 1981 Joint House/Senate Hearings 254

Page
(2) Space Policy Legislation: H.R. 3712 and H.R. 4286 256
5. User Requirements 256
a. NOAA's Findings 256
b. Improving Image Resolution 259
c. Advanced Sensors 259
(1) Multilinear Arrays 263
(2) Stereo Imaging: Stereosat and Mapsat 263
(3) Large Format Camera 265
6. Current Status of Private Sector Takeover 265
E. International Aspects of the Landsat Program and Satellite Remote Sensing 266
1. International use of Landsat Data 266
a. U.S. Government Agencies with International Involvement ... 266
b. Foreign Landsat Receiving Stations 271
c. United Nations Programs 271
d. Issues Concerning Utilization of Landsat Data by Developing Countries 272
2. Remote Sensing Satellite Systems in Other Countries 273
a. The European Space Agency 273
b. France 274
c. Germany 274
d. India 275
e. Japan 275
f. Soviet Union 276
3. Proposals to Establish an International Satellite Remote Sensing System 279
a. Increasing the Role of the United Nations 280
b. U.N. Affiliate Organization 280
c. New International Organization 281
d. Potential Problems with International Operations 281
4. International Legal Problems Associated with Satellite Remote Sensing 282
a. Earth Resources Versus Meteorological Data 282
b. Image Resolution and Prior Consent 283
c. National Sovereignty Issues 283
d. U.N. Efforts to Establish Principles for Remote Sensing Programs 284
II. Applications Explorer Mission Satellites for Remote Sensing and Environmental Observations 288
A. Heat Capacity Mapping Mission (HCMM) 288
B. Stratospheric Aerosol and Gas Experiment (SAGE) 290
C. Magnetic Field Satellite (Magsat) 291
1. Introduction 291
2. The Earth's Magnetic Crust 292
3. The Magsat Mission 292

CHAPTER SIX: OCEAN SENSING SATELLITES

I. Seasat 296
A. Introduction 296
B. Satellite Capabilities 297
C. Data Gathering and Dissemination 297
D. Cost and User Participation 298
E. International Participation 301
F. Spacecraft Failure 301
G. Mission Evaluation 302
1. Marine Weather and Ocean Condition Forecasts 304
2. Offshore Resource Exploration and Development 304
3. Commercial Fishing 304
4. Marine Transportation 304
II. National Oceanic Satellite System (NOSS) 305
A. Introduciton 305
B. Program Plan 305
1. Responsibilities of the Three Agencies 307
2. Support for NOSS 308
C. Program Initiation 309

Page
D. Program Termination 310
E. Possible Replacement Program—ROSS 310
III. Future Proposals 311

CHAPTER SEVEN: GEODYNAMIC SATELLITES

I. Introduction 313
II. Project Anna 317
A. Program Description 317
B. 1962 House Science and Astronautics Committee Hearings 318
1. Security Classification of Project Anna 319
2. Management of Project 320
3. Aftermath 321
III. Explorer Satellites with Geodynamic Missions 322
A. Beacon Explorers, A, B, and C 322
B. GEOS 1 322
C. GEOS 2 323
IV. PAGEOS 323
V. GEOS 3 324
VI. LAGEOS 326
VII. Proposals for Future Civilian Geodynamic Satellites 330

CHAPTER EIGHT: NAVIGATION SATELLITES

I. Transit 337
A. Program History 337
B. Program Description 338
C. Technology 339
II. Technology Improvement Programs for Navigation Satellites 340
III. NAVSTAR Global Positioning System 341
A. Program History 341
1. Navy Program—Timation 341
2. Air Force Program—System 621B 342
3. Combined Programs—Navigation Technology Satellites 342
B. Program Description 343
1. Phase I 345
2. Phase II 345
3. Phase III 346
4. 1977 Program Restructuring 346
5. 1980 Program Restructuring 347
a. Reduction in Number of Satellites 347
b. Delaying Initial Operational Capability 348
c. Fortuna Master Control Center Cancellation 348
d. Block Modifications to NAVSTAR Spacecraft Postponed 348
6. Congressional Concern 348
C. Technology 350
1. Satellites 350
2. Receivers/User Sets 351
D. Civilian Use of NAVSTAR 352
1. Conditions for Civilian Use of NAVSTAR 355
2. Potential of NAVSTAR to Replace Existing Navigation Systems .. 355
a. 1978 and 1981 General Accounting Office Studies 360
b. 1980 Federal Radionavigation Plan Recommendations 360
c. 1981 DOD Schedule of Navigation System Phase-Out 361
3. The 1980 Federal Radionavigation Plan 363
a. Responsibilities of Various Federal Agencies for Navigation Systems 363
b. Significance of Cost to Civilian Users 364
c. International Issues 364
4. Who Should Operate Navigation Systems in the United States? ... 365

CHAPTER NINE: TRACKING AND DATA RELAY SATELLITE SYSTEM

I. Introduction 367
II. System Description 368

Page

III. Program History 372
    A. Lease Versus Purchase Decision 372
        1. 1976 GAO Review 375
        2. Original Contract 375
    B. 1979 Contract Modifications 376
        1. Radio Frequency Interference 376
        2. Other Contract Modifications 377
    C. Shuttle Slippage and Cost Growth 378
        1. 1980 378
        2. 1981 379
    D. TFRSS Security Modifications 379
    E. Inspector General Report 1981 380

UNITED STATES CIVILIAN SPACE PROGRAMS

VOLUME TWO: APPLICATIONS SATELLITES

SCIENCE POLICY RESEARCH DIVISION

CONGRESSIONAL RESEARCH SERVICE

LIBRARY OF CONGRESS

ACKNOWLEDGEMENTS

A study such as this could not have been written without the assistance of a great many people, especially in NASA. The authors would like to express their special appreciation to the following individuals.

NASA HEADQUARTERS

Ken Ando, Office of Space Science and Applications
Lynn Heninger, Office of Legislative Affairs
Mary D. Kerwin, Office of Legislative Affairs
Lynne Murphy, Office of Legislative Affairs
James Welch, Office of Space Science and Applications

OTHER GOVERNMENT AGENCIES

Rick Hale, U.S. General Accounting Office
Charles K. Paul, Agency for International Development
Tom Potts, Extension Service, Beaufort, South Carolina

CONGRESSIONAL RESEARCH SERVICE, SCIENCE POLICY RESEARCH DIVISION

Christine Anderson
Kaseem Hall
Terrence Lisbeth
Shirley Williams

CHAPTER ONE

INTRODUCTION AND SUMMARY

Over the past 23 years of space activities [1], the use of satellites for practical purposes such as communications, navigation, and remote sensing has become commonplace. This report, which comprises the second volume of "United States Civilian Space Programs," details the history of U.S. applications satellites and identifies issues connected with these programs which may be of concern to Congress in the years ahead.

"United States Civilian Space Programs," published in two volumes (Volume I was released in 1981), complements three other studies by the Science Policy Research Division of the Congressional Research Service: Soviet Space Programs, prepared at five year intervals for the Senate Committee on Commerce, Science, and Transportation (previously for the Senate Committee on Aeronautical and Space Science which was abolished in 1976); World-Wide Space Activities, prepared for the House Committee on Science and Technology in 1977; and Space Activities of the United States, Soviet Union, and Other Launching Countries/Organizations (published annually by CRS).

There is a close correlation between civil and military versions of satellites for application purposes, particularly for communications, weather, and geodesy. Nevertheless, the civil and military space communities have maintained separate systems, primarily because of the openness of the civil program and the classified nature of military activities. This report details only civilian satellite activities, with the single exception of navigation satellites, since even though they are military, they are used extensively by the civil sector.

Many of the different types of applications satellites are themselves interrelated. For example, satellites for "remote sensing" of the earth include not only the Landsat series which has become so familiar over the past decade, but also weather satellites, ocean sensing, and geodesy. Many of these satellites carry sensors which can be applicable to other areas of inquiry, for example, GEOS 3, although labeled a geodynamic satellite, carried sensors for studying the ocean. Another illustration is the use of the Tracking and Data Relay Satellite System (TDRSS) for communicating with Earth during the 1980's by most U.S. civil satellites and the space shuttle.

This study encompasses the range of applications where satellites play a key role today. Included are the major areas of communications satellites, meteorological satellites, earth resources and environmental monitoring satellites, ocean sensing satellites, and geodynamic satellites. Each chapter provides a history of the use of satellites for that application area, a description of the technology, and a discussion of the relevant public policy issues related to both the domestic and international aspects of applications satellites. Chapter two highlights specific issues which may be of interest to Congress relevant to the various of applications satellites.

---

[1] Information in this study is current as of Dec. 31, 1981, although some chapters reflect information as recent as March 1983 when work was in progress on the study.

CHAPTER TWO

ISSUES FOR CONGRESSIONAL CONSIDERATION

The United States is at a turning point in many areas of application satellite activities. As technological development continues at a rapid pace and economic and foreign policy pressures increase, the need to resolve issues which have been debated for many years becomes more acute. At the same time, these issues are complex, encompassing both U.S. domestic and international policy, thus making their speedy resolution difficult.

A number of major issues cut across the whole range of applications satellites. For example, as satellite programs move from experimental into operational phases, should the role of the U.S. Government decrease? Related to this is the question of whether the regulatory efforts of Government should be reduced as industry competition increases. Who should be responsible for research and development support for applications satellites—the Government or the private sector—and in which areas should Government funding remain dominant? In summary, where is the appropriate dividing line between public and private sector responsibilities for application satellite programs?

Similarly, the United States is faced with new international policy dilemmas as satellites come into wider use worldwide. How should the United States respond to the growing competition in space from abroad? Furthermore, what role should the United States play as a partner in international projects, whether it be in developing systems, maintaining cooperative programs, or allowing other countries to use U.S. systems? Finally, how can the U.S. Government best represent the interests of this Nation in international organizations, such as Intelsat, the United Nations, and the International Telecommunications Union, particularly in light of growing demands by the less developed countries for such things as equitable access to geostationary orbital positions?

The following chapter highlights issues which may be of interest to the 98th Congress. Further details can be found in chapters three through nine (the appropriate chapter is noted in parentheses).

I. ISSUES CONCERNING COMMUNICATIONS SATELLITES
(Chapter Three)

A. Government Versus Private Sector Roles

The mixture of public and private sector involvement in communications satellite development in the United States has contributed significantly to its position of prominence today. At the same time, however, it has created certain tensions and raised difficult questions for policymakers who attempt to delineate responsibilities between the two sectors. The role of the U.S. Government has been critical—both as a result of the space program and through legislation, such as the Communications Satellite Act of 1962—in shaping the development of communications satellite activities.

As these efforts move increasingly into commercial as well as operational phases, issues develop over the continued appropriateness of a considerable Government presence. The emphasis on private involvement in communications satellites is longstanding as reflected in the Communications Satellite Act itself. The Act created a largely independent, publicly owned entity, the Communications Satellite Corporation (Comsat), as the vehicle to put into operation at the earliest possible date an effective satellite communications systems. In recent years, there has been an effort to increasingly remove Government from communications satellite activities and promote private initiatives in this expanding field.

This shift can be seen in a number of areas. One is public service satellites where government programs have been eliminated by recent budget cuts. Another example involves support for research and development (R&D) funding. The National Aeronautics and Space Administration (NASA) was the mainstay of R&D funding for communications satellites until the early 1970's when it decreased its level of support and attempted to rely more on the private sector. Although some funding was reinstated in 1979, recent budget cuts may affect the level of R&D support by NASA. The private sector seems willing to proceed in R&D areas where direct payoffs are discernable. Can, however, private corporations be expected to support R&D efforts where the costs are high and the benefits are extremely long range? Are certain programs so important to the national interest that they warrant U.S. Government support? Does the Government need to determine what our priorities are in communications satellites?

This situation is accented by the increasing competition in communications satellites from abroad. Some industry observers contend that unless the U.S. Government takes affirmative action to support communications satellite development, U.S. enterprises may lose their dominant position worldwide. How should the United States respond to the changing international setting in which foreign facilities and technological advancements threaten the competitiveness of U.S. products and services? How can the U.S. Government support private sector initiatives other than through direct R&D funding?

B. Promotion of Competition

It is the preference within the United States to rely on marketplace competition rather than Government regulation whenever possible. The Federal Communications Commission (FCC) has moved increasingly in recent years to promote competition within the U.S. telecommunication industry. Specifically, it has sought to foster new and diverse services, make segments of the industry more open to new entrants, and reduce costs of equipment and services.

While this deregulatory approach receives general support, it also causes new concerns and calls for reassessment of policies and practices. How can the transition from a highly regulated to a deregulated environment be made as equitable as possible for all the participants? How are consumers protected as industry structures change and Government controls decrease? What steps need to be taken to insure that national priorities, such as defense and public service, are met while promoting competition among private enterprises? What efforts can Government undertake to promote further competition?

The issue of foreign competition is relevant to this area as well. For example, what effect does the U.S. procompetitive approach have on international telecommunications and our relationship with foreign telecommunications authorities and international organizations, such as Intelsat? How can we insure that U.S. firms have equal opportunities to compete in foreign markets to foreign firms providing telecommunications products and services in the United States?

C. INTERNATIONAL COOPERATION

The United States took the lead in communications satellites, but from the beginning recognized the importance of establishing a viable global communications satellite network. In a number of international efforts to exploit the potential of communications satellites, the United States played a pivotal role. Included are such activities as Intelsat, Inmarsat, and Aerosat. While the United States remains firmly committed to international cooperation, these activities also pose difficulties for policymakers attempting to balance competing concerns of the United States and foreign governments.

As other nations become more aware of the utility of communications satellites there is increasing pressure on the position of the United States. Developing countries in particular are making demands for more equitable access to frequency allocations and the geostationary orbit, for example. How can the United States effectively respond to these demands and others for improved technical assistance? How can the United States defend the concept of free flow of information against efforts to demand prior consent over the broadcasting of programs into a country? How should our foreign policy concerns be weighed against the needs of U.S. providers and users of satellite communications services and systems?

As technology improves, demands for specialized services grow, the worldwide use of communications satellites improves, and pressures from foreign governments increase, it may be necessary to reassess U.S. positions in international areans and programs. What steps can the Government take to improve U.S. representation at international meetings? Can the U.S. private sector be a more effective partner in international cooperative efforts or should the U.S. Government take the lead responsibility? How can the U.S. Government most effectively work with the private sector to promote the interests of the United States in cooperative international arrangements? Should the U.S. Government develop a strategy for international communications policy? If so, what should its priorities be? Under what conditions should other countries be permitted to utilize U.S. systems? Finally, how can the United States promote the continued development of communications satellite systems worldwide to the benefit of all nations, while also supporting the goals of the United States?

II. ISSUES CONCERNING CIVIL LAND REMOTE SENSING SATELLITES (Chapter Five)

A. TRANSFER OF LANDSAT TO THE PRIVATE SECTOR

The issue of when to transfer the Landsat program out of NASA (which is a research and development agency) has been debated for many years. In 1979, NOAA was given responsibility for operating the system, with the expectation that control would be transferred to the private sector within a decade. The Reagan administration has sought to speed up that timetable, with private sector operation at the earliest feasible date.

Among the issues involved in private sector takeover of Landsat is whether the entire system (both the space and ground segments) should be given to the private sector, or if the Government should retain responsibility for the satellites and associated control functions, while transferring only the data processing and dissemination segment to the private sector. If either or both parts of the system are transferred out of the Government, should the Government designate an entity to perform the task, or should there be a competitive selection process?

In order to assure the financial viability of such a venture, should the Government offer guarantees to the private sector operator, for example to purchase a certain amount of data? Should the Government agree to permit private sector operation of weather satellites as well, as has been suggested by Comsat, to assist in making the venture more attractive to the private sector? If the private company decides that it does not want to continue operating the system (for financial or other reasons), will it be more expensive for the Government take back the system than if it had kept it in the first place? Would the Government retain responsibility for performing advanced research and development for remote sensing systems, or would this also become the responsibility of the private sector?

Another concern is whether private sector operation of Landsat would lead to price increases for the data that would present difficulties for certain classes of users, such as State and local governments and foreign users (particularly the less developed countries).

Retaining Government control over the program might also present problems. How capable would the Government be in aggregating the user market? Which agency would pay for future satellites and shuttle-type experiments—NASA, NOAA, or the agency most likely to use the data (for example, the Department of Agriculture for sensors particularly suited to crop monitoring)?

B. FUTURE OF THE U.S. CIVIL LAND REMOTE SENSING PROGRAM

As of the end of 1981, the U.S. Government is committed to launching only two more free-flying civil land remote sensing satellites (Landsat D in 1982 and its backup, Landsat D′, in 1985 if Landsat D does not fail prematurely). After that, the future of the

U.S. civil land remote sensing program will presumably be in the hands of the private sector.

What will happen if no private sector company is willing to pick up the program—will no further satellites be launched? NASA is planning to develop advanced remote sensing technology (such as multilinear arrays), but these experiments will fly only on the space shuttle, not on free-flying satellites which can remain in orbit for several years. The transition of experimental equipment from the shuttle to free-flyers will be left to the user community. What will happen to U.S. leadership in remote sensing technology if the user community does not choose to use these new technologies on free-flying satellites and they become mothballed?

At the same time, governmental programs for demonstrating the utility of remote sensing data, such as AgRISTARS, are in jeopardy because of the budget situation. Should such program be given a higher priority, or has the value of this data already been shown so that these programs are no longer needed?

C. Coordination with the Department of Defense

Data from military reconnaissance satellites might be useful for certain classes of civil users of remote sensing data. Although precise information is not available in the open literature, it is assumed that military satellites have resolutions of better than 1 meter, compared to 30 meter resolution with the Landsat D thematic mapper. Would it be possible to release military reconnaissance data, particularly older data which might no longer have national security implications, to civil users?

Another issue related to military coordination is that of the limitation of image resolution. President Carter's first space policy directive in 1978 apparently included language limiting the resolution of civil land remote sensing satellites to no more than 10 meters (the full document is classified, so the exact wording cannot be determined from open sources). One advantage of remote sensing from space is that it provides a synoptic view of larger areas than can be viewed from aircraft, so the question arises as to how many users really require better than 10 meter resolution, particularly since the cost for the system would probably be increasingly expensive as resolution improves. On the other hand, there may be a few users (such as coastal zone managers) who could truly benefit from higher resolution images. How serious is the national security threat if higher resolution instruments are flown on civil satellites, since the Soviet Union already has its own high resolution reconnaissance satellites and other countries may soon follow suit?

D. International Issues

Data from civil land remote sensing satellites provides information on a country's natural resources and therefore can be of significant importance to that country's national security (particularly from an economic standpoint). As a result, many countries would like to have the right to prior consent over which other countries are given access to that data. The U.S. position is to provide access to anyone willing to pay for the data. The decade-old debate at the United Nations over this issue appears to be stalemated, and now awaits concessions from either or both sides. If the United States is not willing to compromise its open skies policy, is there any point in our continuing to debate the topic at the United Nations? Realistically, can any country expecting to have a profitmaking satellite remote sensing program afford to allow the prior consent principle to go into effect?

Another international issue concerns whether an international agency should be established to expedite the distribution of remote sensing data to other countries. A number of suggestions have been made, including increasing the role of the United Nations either by establishing a specialized agency to handle such activities or by expanding existing United Nations programs in this area. Should the United States support such discussions, or is the current United Nations satellite remote sensing effort adequate? U.S. programs through NASA and AID to assist developing countries in using remote sensing data appear to be coming to a halt. Would a United Nations agency be a viable alternative to these purely U.S. initiatives, at less expense since other countries would be paying for part of the United Nations efforts? In the absence of a United Nations agency, should the U.S. programs be reinvigorated?

III. REMOTE SENSING OF THE OCEANS FROM SPACE
(Chapter Six)

The United States has launched only one satellite, Seasat, dedicated to studying the Earth's oceans. An electrical malfunction caused the satellite to cease operating after 100 days in orbit. A proposed follow-on program NOSS, was cancelled because of budgetary constraints, and the United States currently has no plans for orbiting an ocean sensing satellite, although the back-up Seasat radar experiment was flown on the second test flight of the space shuttle in November 1981.

Should the United States reinstate a free-flying ocean sensing program or is there insufficient need for such data? Was the Seasat program, as short-lived as it was, successful, or were lessons learned which should be applied to future systems (other than the obvious lessons concerning the electrical supply subsystem which failed)? Should the private sector be expected to pursue such activities on its own instead of relying on the Federal Government? If the Government pursues an ocean satellite program should it be another tri-agency [NASA, NOAA, Navy] effort as NOSS would have been, or are the coordination problems (particularly in terms of budget matters) too much of a drawback?

Several other countries (notably the Soviet Union, Japan and the European Space Agency) have launched or are planning to launch ocean sensing satellites. Should the United States attempt to be in the forefront of this technology, or allow the lead to go to these other nations? What international issues might arise from satellite ocean sensing? For example, is there likely to be concern about access to data about fishing grounds and oil/mineral exploration sites that might be within a country's territorial limits (particularly for those countries with 200 mile limits)? What actions are being taken by the United States to prepare for these potential issues?

IV. ISSUES CONCERNING METEOROLOGICAL SATELLITES

A. Number of U.S. Polar-Orbiting Meteorological Satellites (Chapter Four)

As a budget cutting move, the suggestion has been made to reduce the number of U.S. polar-orbiting meteorological satellites in orbit at one time from two to one. Satellites would then be launched at 18 month intervals. Are the cost saving expected to result from this move justified by the reduction in data that will be available to weather forecasters, particularly in the equatorial area where many tropical storms originate? How would this action affect the Search and Rescue project, since the transponders required for this activity are carried on the polar orbiting weather satellites? What are the implications for foreign users of data from these satellites?

B. Operation of Meteorological Satellites by the Private Sector (Chapter Five)

As part of its proposal to take over the Landsat land remote sensing satellites, Comsat also asked that it be given operational control of other governmental remote sensing satellites. At this time, that would involve only meteorological satellites (but could include ocean sensing if such a program were reinstituted). Would operation of the meteorological satellites by the private sector be cost effective considering that the U.S. Government would be the customer for an estimated 95 percent of the data? Would such a transfer impact national security requirements since the Department of Defense (DOD) utilizes data from the civil weather satellites to augment data from the Defense Meteorological Satellite Program?

V. ISSUES CONCERNING NAVIGATION SATELLITES FOR CIVIL USERS (Chapter Eight)

A. Civil Access to NAVSTAR in Times of Crisis

The civilian community has been allowed access to the U.S. navigation satellite system (Transit) since the late 1960's although the satellites are developed, procured and operated by DOD. United States and international civil users have come to depend on the Transit system—with its low-cost receivers and free access to the satellite signals—for their navigational requirements.

The new NAVSTAR Global Positioning System can provide data with considerably better accuracy, and in three dimensions (latitude, longitude, and altitude) instead of the two-dimensions available with Transit. As a result, new restrictions may be imposed on users of the NAVSTAR system. For example, civil users are expected to have access to only one NAVSTAR channel that will have an accuracy of 200 meters, and not to the higher accuracy (16 meter) channel. DOD has promised to periodically review whether the 200 meter accuracy available to civil users can be increased, but there are no guarantees that such an action will take place.

There are also no guarantees that civil users will be allowed access to the satellite system in the event of hostilities. Thus, users might become dependent on the system, only to have access denied at a critical moment. (This restriction may also apply to allied military organizations like NATO which apparently have been given no assurances that they will be able to access the system in times of crisis. Since this is a military rather than civil issue, however, it is not discussed in this report).

Should the U.S. Government offer assurances to the domestic and international civil community that they will be able to access at least the less accurate NAVSTAR channel in times of crisis? Without such assurances, is there a need to retain existing navigation systems (including Transit as well as terrestrial systems such as LORAN-C) despite pressures to phase out many of these systems to reduce costs? Should an alternative international satellite navigation system be established, perhaps through Inmarsat? Could the civil community take over the Transit program once NAVSTAR is operational, or is that system's two-dimensional data capability insufficient for current and future needs?

B. CHARGING FEES FOR ACCESS TO NAVSTAR

Another issue in civil utilization of NAVSTAR is the possibility that DOD will charge fees to the civil community for access to the system in order to recover its development costs (access to Transit is free). How would the imposition of such fees affect civil use of NAVSTAR? Alternatively, since over 90 percent of Transit use is by the civil sector, and assuming the same percentage could eventually apply to NAVSTAR, should the program simply be transferred to a civil agency such as the Department of Transportation, with appropriate reimbursement to DOD by the agency, instead of charging fees to individual users? What would be the national security implications of such a transfer?

VI. THE TRACKING AND DATA RELAY SATELLITE SYSTEM

(Chapter Nine)

The costs for the Tracking and Data Relay Satellite System (TDRSS) have risen dramatically over the years, primarily as the result of delays in getting the system into orbit and the costs associated with interest payments on the TDRSS loan during years of high inflation.

The first TDRSS satellite is scheduled for launch in early 1983, so the major remaining issues about this program concern lessons learned from the TDRSS experience, and whether or not NASA should purchase the system from Spacecom now, rather than ten years after operations begin as originally planned. Were the problems encountered with TDRSS peculiar to this system, or are there lessons which should be applied to other governmental plans to lease satellite services from private companies (such as DOD's Leasat program)? What would be gained by continuing to keep the original lease arrangement with Spacecom, rather than allowing NASA to purchase the system now? Conversely, can NASA afford to purchase the system from Spacecom during a time of severe budget constraints on the agency?

CHAPTER THREE

COMMUNICATIONS SATELLITES

I. INTRODUCTION

Communications satellites are one of the great benefits resulting from the promise of space exploration. These satellites receive signals from Earth station antennas, amplify them and then relay them back to another antenna on Earth. Because communications satellites operate in what is known as geostationary orbit [GEO]—an orbital path 22,300 miles above the Earth's Equator—they complete one revolution of the Earth at precisely the same rate as the Earth makes one revolution on its axis, thereby staying at the same point relative to any point on the Earth at all times. Coverage of almost the whole Earth can be accomplished with three satellites generally located over the Atlantic, Pacific, and Indian Ocean regions.

Communications satellites are insensitive to the distance that a message would have to travel terrestrially and thus provide vast new opportunities for linking remote areas and locations lacking ground communications facilities. But, the ability to serve distant locations is only one of the advantages offered by communications satellites. During the more than fifteen years since communications satellites were first launched by the International Telecommunications Satellite Organization [Intelsat], the capacity of a single satellite has increased by a factor of 50 while the cost per circuit-year has decreased by nearly the same amount. As a result, satellites began to be viewed increasingly as an attractive alternative to more traditional cable communications lines and today they are employed for a wide range of voice, data, and video transmissions.

This growth curve in satellite communications can be expected to continue as new approaches and technologies, such as direct broadcast satellites, become operational. Indeed, the number of communications satellites scheduled to be launched both in the United States and abroad during the next several years is impressive. In addition to the growing fleet of U.S. domestic communications satellites and the expanding number of Intelsat satellites, a number of foreign nations are developing their own domestic communications satellites capabilities and several regional systems are coming into existence.

The following sections of this chapter will highlight the major civilian application areas of communications satellites in the United States and internationally. Included is a history of communications satellites; the formation of the Communications Satellite Corporation (Comsat) and Intelsat resulting from the Communications Satellites Act of 1962; uses of communications satellites in both the aerospace and maritime industries; public service satellite programs; search and rescue systems; amateur communications satellites activities; domestic communications satellites in the United States; and the emerging area of direct broadcast satellites. In addition to a history of these efforts and an explanation of the technology involved, each section also addresses relevant public policy issues.

II. COMMUNICATIONS SATELLITE CORPORATION [COMSAT]

A. Introduction

Charging Vice President Lyndon Johnson with the leadership role in determining how a communications satellite system could be put in operation at "the earliest practical time," President Kennedy stressed the peaceful and international character of any such system. Outlining the scope of the task to Johnson in a June 15, 1961 letter, Kennedy wrote: "I am anxious that this new technology be applied to serve the rapidly expanding communications needs of this and other nations on a global basis, giving particular attention to those of this hemisphere and newly developing nations throughout the world." [1]

The development of effective satellite communications was a key element of the Kennedy space program, itself the centerpiece of the New Frontier. A satellite system's contributions to international understanding, peace, and commerce were the political and policy attractions that led the administration to promote legislation; equally important, a system developed by the United States could be a valuable public opinion tool in a still chilly cold war. Testifying before the Senate Aeronautical and Space Sciences Committee in March 1962, George C. McGhee, Undersecretary of State for Political Affairs, urged speedy action on the pending Communications Satellite Act: "It would make possible a closer interlinking of remote nations, leading to a freer and more rapid exchange of information and ideas, and a more rapid exchange of governmental and private communications which would greatly improve international understanding . . . We are hopeful that the Soviet Union, which cosponsored the United Nations resolution looking toward a global and nondiscriminatory satellite system, will join with us in implementing this objective." [2]

Out of this push for legislation emerged the Communications Satellite Corporation—Comsat—child of the compromise that was the Communications Satellite Act of 1962. While there was agreement on the purposes and scope of a communications satellite system, controversy surrounded its ownership and operation. Some argued that the development of the technology at public expense, coupled with the purpose of a satellite system in demonstrating United States capabilities and good will, demanded Government ownership and operation. Others felt that existing private companies would be the most effective developers and operators: didn't the United States have the best, and cheapest, communications system in the world? Yet a third group agreed that private enterprise was probably more efficient, but felt that the purposes of the system and the dangers of monopolization by existing private firms dictated the need for a new approach, a public corporation. Much of the concern with private ownership, both within the administration and on Capitol Hill, revolved around the question of monopolization. According to press reports, both the White House and some quarters on the Hill feared that any private consortium or similar venture would be dominated by AT&T, "which inevitably would gain control by the preponderance of its investment." [3]

---

[1] New York Times, June 25, 1961, p. 36.
[2] New York Times, Mar. 1, 1962, p. 5.

In this initial debate the critical policy questions of Comsat's 20 years of life were highlighted, whether or not they were central elements of the legislative debate: who should own and operate the communications satellite system? What business structure should be permitted? Did the international purposes of the original structure preclude a different domestic approach? The dominance by these questions of the policy debate surrounding Comsat was constantly reflected in the events of the last two decades. The concerns over the potential monopolization of satellite services by AT&T in the early 1960s are echoed in current proposals to alter Comsat's structure. The focus on international operations and objectives in the original legislative process created an element of uncertainty in the plans and direction of Comsat in the early 1970s. The following pages explore these policy questions, describing the legislative process that created Comsat, the impact of the domestic satellite decision by the Federal Communications Commission in 1972 on Comsat's direction, the current structure and operations of Comsat, proposals for change in its structure (particularly the FCC study), and the issues which may face the Congress.

B. THE COMMUNICATIONS SATELLITE ACT OF 1962 AND THE ORIGINS OF COMSAT

On August 31, 1962, President Kennedy signed into law the communications Satellite Act, perhaps the most significant addition to communications law since the passage of the Communications Act in 1934.[4] The Satellite Act provided that: (1) Comsat would be a private corporation in order to use the profit motive to spur development; (2) Comsat would operate under a broad international charter so that a global system would evolve, not one which served only high profit areas—the system should be accessible to all nations, including those to which service would show no immediate profit; and, (3) Comsat would be organized and operated so that no single company could dominate the system through ownership or patent control—the public would own 50 percent of the stock and the international carriers would own the remaining 50 percent. At the same time, the legislation set the stage for the the future by emphasizing the international mission of Comsat and by reserving domestic satellite operations for future consideration. In that vein, section 102 described underlying policy of the act:

---

[3] New York Times, Aug. 4, 1961, p. 2; Dec. 6, 1961, p. 23.

[4] Public Law 87-624; 47 U.S.C. 701 et seq.

(a) The Congress declares that it is the policy of the United States to establish, in conjunction and cooperation with other countries, as expeditiously as practicable a commercial communications satellite system, as part of an improved global communications network, which will be responsive to public needs and national objectives, which will serve the communications needs of the United States "and other countries, and which will contribute to world peace and understanding.

(b) The new and expanded telecommunication services are to be made available as promptly as possible and are to be entended to provide global coverage at the earliest practicable date. In effectuating this program, care and attention will be directed toward providing such services to economically less developed countries and areas as well as those more highly developed, toward efficient use of the spectrum, and toward the reflection of the benefits of the economical use of the electromagnetic frequency of this new technology in both quality or services and charges for such services

(c) In order to facilitate this development and to provide for the widest possible participation by private enterprise, United States participation in the global system shall be in the form of a private corporation subject to appropriate governmental regulation. It is the intent of Congress that all authorized users shall have nondiscriminatory access to the system; that the corporation created under this chapter be so organized and operated as to maintain and strengthen competition in the provision of communications services to the public; and that the activities of the corporation created under this chapter and of the persons or companies participating in the ownership of the corporation shall be consistent with the Federal antitrust laws.

(d) It is not the intent of Congress by this chapter to preclude the use of the communications satellite system for domestic communication service where consistent with the provisions of this chapter nor to preclude the creation of additional communications satellite systems, if required to meet unique governmental needs or if otherwise required in the national interest.[5]

Comsat was incorporated in the District of Columbia in 1963. On August 20, 1964, Comsat became a signatory to the articles establishing the International Telecommunications Satellite [Intelsat] system; today Comsat acts as technical manager under contract to Intelsat of that global system on behalf of the 106 participating nations.

Both the operative provisions of the legislation and the policy enunciated in it were the result of substantial administration and congressional deliberation.

1. Policy development in the executive branch

The move toward the commercial and peaceful use of space began when NASA Administrator T. Keith Glennan announced, on October 12, 1960, that NASA would launch and evaluate private communications satellites. The announcement, interpreted by many as a major new policy statement, was the result of pressure for a Government policy from several quarters.[6]

Private industry wanted the communications satellite frontier opened. In response to the announcement, General Electric formed Communications Satellite Inc. in April of 1961. The GE project was initiated as an international venture to develop a commercial communications satellite system.[7] At the same time, AT&T developed Telstar for launch by NASA. AT&T viewed it as the prototype facility for a viable commercial communications satellite system.[8] It applied to the FCC for the authority to launch satellites and operate such a system on October 21, 1960, scarcely two weeks after the NASA announcement. The FCC authorized AT&T to establish on an experimental basis the first transatlantic satellite link on January 19, 1961.

---

[5] 47 U.S.C. 701.

[6] "NASA Will Launch Commercial Satellites," Aviation Week, Oct. 7, 1960.

[7] Smythe, D. W. "Public Benefit v. Private Privilege," The Nation, Oct. 21, 1961. p. 265.

[8] New York Times, July 2, 1961. p. 8.

United States space policy, however, was still far from certain. But President Kennedy was committed to the space program and felt a concrete satellite policy was necessary to strengthen it. Kennedy particularly wanted to develop communications satellites; he saw U.S. technological superiority in the area as a way to take the initiative in space away from the Russians.[9]

On February 28, 1961, the Federal Communications Commission and NASA released the text of a "memorandum of understanding." The document flatly stated that communications satellites were an imminent possibility. It went on to define NASA's functions as technical and operational, reserving to the FCC the key policy role. In the words of the memo, the FCC was to work "toward the development of communications policy on the implementation and utilization of space technology through the licensing and regulation of U.S. common carriers."[10] Responding to this mandate, the Commission opened Docket 14024 on March 29. In its notice, the FCC sought comments regarding the administrative and regulatory structure of a commercial communications satellite system.

As the FCC opened its inquiry, President Kennedy was reestablishing the National Aeronautics and Space Council, which had become dormant in the last years of the Eisenhower Administration. Asking Congress for reauthorization of the Council, Kennedy proceeded to appoint Vice President Johnson as its Chairman and Dr. Edward C. Welsh as its Executive Director. On April 25, Congress reactivated the Space Council. By this time the FCC already had received seven proposals for satellite communications systems through Docket 14024.[11]

Those seven proposals were met with a Justice Department filing on May 5 which outlined several antitrust considerations which it felt must be taken into account in determining the development and operation of any communications satellite system:

(1) the need for joint ownership by all carriers;

(2) the need for nondiscriminatory access to the facilities;

(3) the need to permit ownership by any interested equipment suppliers; and

(4) the need to assure competitive procurement of equipment.

AT&T objected to the proposal that equipment suppliers be permitted to join in the venture. General Electric supported the Justice Department, arguing that because some manufacturers would be included in ownership, at least indirectly, because they were subsidiaries of carriers, other manufacturers must be allowed to have an ownership interest.[12]

In late May, the FCC issued its First Report in Docket 14024. The report proposed a joint venture limited to the international record carriers [IRC's] and AT&T. The Commission concluded that:

---

[9] Jefferson, P., and J. Benson. "Edward C. Welsh: A Personal History of the Comsat Act." Satellite Communications, January 1979. p. 22.

[10] Moe, R. C. "Telecommunications Policy: The Legislative History of the Communications Satellite Act of 1962." Doctoral Thesis, Columbia University (1965). p. 115.

[11] Jefferson, P., and J. Benson. Edward C. Welsh. Satellite Communications, January 1979. p. 22.

[12] Moe, R. C. "Telecommunications Policy." Thesis, Columbia. p. 121.

(a) It appears to be generally accepted that because of considerations of practical economics and technical limitations, it will not be feasible for some time to come to accommodate more than one commercial satellite system.

(b) Communication via satellite will be a supplement to, rather than a substitute for, existing communications systems operated by the international common carriers, thereby becoming an integral part of the total communications system of each such carrier.

(c) The responses filed by the international carriers express a willingness and indicate a capability to marshal their respective resources for the purposes of developing a satellite communications facility.

(d) By reason of their experience in and responsibility for furnishing international communications service, the international carriers are logically the ones best qualified to determine the nature and extent of the facilities best suited to their needs and those of their foreign correspondents, with whom they have longstanding and effective relationships and who necessarily will have a substantial interest in the operations of any satellite system.

(e) Under the Communications Act, the international carriers are obligated to furnish the public with adequate, efficient service at reasonable charges, and this obligation can best be discharged by those carriers maintaining, as far as possible, the greatest degree of direct control and responsibility over the facilities employed in this service.

In effect, the Commission was proposing that satellites be treated in the same way that the undersea cables were—facilities jointly owned by those who used them.

Following publication of the First Report, the Commission held a conference with industry on the actual configuration of any communications satellite system. At that conference an ad hoc industry committee was proposed to formulate the terms, conditions and operational structure of the system. The Commission established the committee under Docket 14024 to consider the "formation of a plan of organization or joint venture to establish a commercially operable satellite communications system." The committee was composed exclusively of common carriers.[13]

Concerned with the FCC proceedings, particularly the Commission's deference to the carriers, President Kennedy directed the Vice President to conduct a study to determine how, and under what structure, a communications satellite system could be put in operation at "the earliest practicable time." The "public interest" was to be the primary consideration in any proposals that might be made. The Space Council had formal responsibility for the study and Dr. Welsh did the bulk of the work. Welsh consulted with industry and a wide variety of Government agencies.[14]

Motivated by concerns over AT&T monopolization of any satellite system left solely in the hands of the carriers, several congressional committees held hearings in June, July, and early August. While the Space Council was deliberating, this series of public hearings highlighted antitrust concerns.

The Space Council delivered its study to the President on July 16, a month after they were given the task. The study recommended private ownership of the United States portion of an international communications satellite system. It proposed some Government controls on that ownership, however, largely to assure against monopolization. On July 24, 1961, President Kennedy issued a "Communication Satellite Policy" based on the recommendations of the Space Council.[15] In essence, the policy called for nondiscriminatory access to the system and competitive bidding in the acquisition of equipment. The statement also reemphasized the global character of any satellite system and called for "foreign participation through ownership."

---

[13] See FCC report of the Ad Hoc Carrier Committee, docket 14024, Oct. 12, 1961.

[14] Jefferson and Benson, "Edward C. Welsh, Satellite Communications," January 1979, p. 22.

[15] Department of State Bulletin, Aug. 14, 1961, p. 273.

Three months later, in mid-October, the Ad Hoc Carrier Committee established by the FCC filed its report. It recommended that a nonprofit corporation, owned by the IRC's and AT&T, be formed to run any satellite system; each carrier, however, would own its own ground stations.

At the beginning of November, the President called on Dr. Welsh to draft legislation which would implement the administration policy adopted that summer. Welsh drafted a bill which created a profit-making quasi-public corporation to operate a communications satellite system. The legislation provided for a limited ownership interest by the international common carriers but vested real control in voting stock to be held by the public. The bill also vested substantial control of the corporation's relationships with foreign governments and carriers in the hands of the State Department and the President. The draft did provide, however, that the corporation would represent the interests of the United States within whatever structure was established to manage the global system. The legislation was introduced on February 7, 1962 by Senators Kerr and Magnuson in the Senate and by Congressman George Miller in the House.[16]

The administration bill, however, was not the first introduced. On January 11, Senator Kerr had introduced S. 2650, an amendment to the NASA Act of 1958. That legislation created a satellite communications corporation owned and operated exclusively by the international carriers. The presence of an alternative—particularly one sponsored by one of the most powerful men in the Senate—did not bode well for the smooth passage of the administration proposal.

2. The congressional process

The administration anticipated that its proposal would "sail through Congress with no great fight," but after a rocky week of hearings, the bill was not expected to pass without considerable change.[17] In part, the difficulty flowed from a lack of administration leadership. Dr. Welsh, the architect of the policy, draughtsman of the bill and logical administration spokesman, had been forced to take a long rest for health reasons. To fill his shoes, the President drafted Deputy Attorney General Nicholas Katzenbach.[18]

Katzenbach was a novice in the field and the bill was heavily lobbied by the carriers, who received strong support from Senator Robert Kerr, Chairman of the Committee on Aeronautical and Space Sciences. Kerr was committed to substantially amending the administration bill. At the height of his power in the early sixties, Kerr was called the "uncrowned king of the Senate" by the press. Intent on amendment rather than moving his own bill, Kerr employed a variety of procedural manuveurs to keep the administration at a disadvantage.[19]

---

[16] 87th Congress, S. 2814; H.R. 10138.

[17] New York Times, Mar. 4, 1962, p. 1.

[18] Moe, R. C. "Telecommunications Policy." Thesis, Columbia. p. 85.

In the midst of this confrontation between Kerr and the administration over the role of the carriers in the ownership and operation of any satellite system, yet a third bill appeared. Introduced on February 26 by Senator Kefauver, this legislation provided for Government ownership of the system. Kefauver offered three arguments in support of the bill: first, that the taxpayers had financed the technology and should retain ownership; second, that a private company would inevitably be dominated by AT&T; and, third, that the process of creating a private company would slow development of an operational system.[20]

Kerr and Senator Symington quickly attacked and derailed the Kefauver bill. One observer wrote that Kefauver's "obvious lack of knowledge as to the technology of space communications" undercut his arguments.[21] The Senator from Tennessee, however, did not give up without a fight. Kefauver held 9 days of hearings before the Subcommittee on Antitrust and Monopoly of the Senate Judiciary Committee which he chaired. Kerr protested that the hearings were improper—the bill had not been referred to Judiciary—but Kefauver went ahead, though ultimately to no avail.[22]

In markup, the Committee on Aeronautical and Space Sciences amended the administration bill at several points, four of them of considerable significance:

(1) the Government's authority to inspect the books of the corporation was removed, largely on the theory that the three Presidential appointees on the Board of Directors made the provision unnecessary;

(2) the FCC was given the authority to license both the corporation and existing common carriers to build and operate ground stations, with provisions for nondiscriminatory access;

(3) the Board of Directors was increased to 15 members, 6 elected by the carriers, 6 elected by the public stockholders, and 3 appointed by the President; and,

(4) the role of the State Department and the President in controlling the corporations relationships with foreign governments and foreign carriers was eliminated—all the corporation had to do was notify the State Department of its contacts with foreign authorities; State was then required to inform the corporation of any foreign policy consideration.[23]

The Senate Commerce Committee, to which the bill had been jointly referred, made two further changes of importance before sending it to the floor. First, the committee added the provision that permitted the communications satellite system to be used for domestic as well as international services. Second, language was added requiring competitive bidding for equipment and services used in the construction of ground stations whether the stations were built by carriers or the corporation.[24]

---

[19] New York Times, Mr. 4, 1962, p. 1; Moe, R. C. "Telecommunications Policy." Thesis, Columbia. pp. 184-186.

[20] Moe, R. C. "Telecommunications Policy." thesis, Columbia. pp. 186-188.

[21] Ibid., p. 188.

[22] Lloyd, D. M. "Communications Satellites in Political Orbit (1968)," p. 55.

[23] Ibid., pp. 65-68.

[24] Ibid., pp. 68-73.

Senate floor debate centered on the question of Government ownership. After extended debate, a filibuster, and a historic cloture vote, however, the bill passed the Senate with no amendments beyond those made in the Commerce Committee on August 17. On August 27 the House acceeded to the Senate amendments and sent the bill to the President.[25]

Comsat had been created, largely an independent publicly owned company, but in some critical ways the creature of Government. The President was required under the Act to "exercise such supervision over relationships of the corporation with foreign governments or entities or with international bodies as may be appropriate to assure that such relationships shall be consistent with the national interest and foreign policy of the United States." [26] The Federal Communications Commission was given the mandate to "insure effective competition" in the purchase of telecommunications goods and services by the corporation; the Commission was also expressly required to regulate the allocation of facilities by Comsat to the users of the satellite system.[27] Finally, Comsat was required to forward to the President and the Congress each year "a comprehensive and detailed report of its activities, operations, and accomplishments. . . ." [28] While none of these requirements was necessarily burdensome, they were clear ties to the Government. Comsat was not a creature absolutely free to do as it wished.[29] Equally important, while the corporation was in theory a private, profit-seeking entity, it could only seek those profits in the "commercial satellite communications" industry—it was unclear whether it could diversify into other lines of activity.

C. COMSAT IN OPERATION

The smooth road to profit and prestige that many had envisioned for Comsat never materialized. The way proved rocky. Beginning with quarrels over rates and the relative merits of cable as opposed to satellite, continuing with the FCC's domestic satellite decision, and culminating in the recent, congressionally mandated FCC report on Comsat's structure and operations, the corporation has neither made as much money nor wielded as much power as Senator Kerr predicted and Senator Kefauver feared.

1. Cable versus satellite and the domestic satellite decision

Comsat's first serious public controversy centered on the rates it proposed for transmitting television signals between the United States and Europe over Early Bird, its first operational satellite. Both the European broadcasting authorities and the American networks protested strongly and with some success.[30] But a more important continuing struggle began with its first operations and resurfaced from time to time throughout the past two decades: the issues of the comparative economic and technical merits of cable transmission facilities and satellite facilities.

---

[25] Moe, C. R. "Telecommunications Policy." Thesis, Columbia, pp. 209–212.

[26] 47 U.S.C. 721(a)(4).

[27] 47 U.S.C. 721(c).

[28] 47 U.S.C. 744(b).

[29] Some of the requirements were given even less onerous than they seem on their face. The President's role in relations with foreign governments, for example, was tempered by the limitation of the State Department's role in any negotiations to that of an adviser to the corporation. 47 U.S.C. 742.

[30] Time, June 25, 1965, p. 88.

In April 1966 AT&T requested authorization from the FCC to lay a high-capacity cable serving the Caribbean basin. Comsat objected, arguing that the proposal would damage the continued development of the global communications satellite system. Diverting Caribbean traffic to cable would increase the cost per channel by 35 percent throughout the Intelsat system. Comsat alleged in a petition to deny filed with the FCC.[31] The first battle in a continuing struggle had been joined; the FCC finally approved the cable with the caveat that the traffic between the United States and Puerto Rico (the terminal point of the cable) must be divided equally between satellite facilities and the cable.

In February 1969 the controversy boiled up again. Comsat petitioned the FCC to compel AT&T and ITT to live up to the terms of the Commission order authorizing the Caribbean cable. Comsat argued that the international carriers and cable owners promised to lease 100 circuits but breached that commitment by leasing only 70. The carriers responded that only 140 circuits were actually needed to handle existing traffic, although a key element in the justification for constructing the cable initially had been the need for 200 circuits serving the Puerto Rican terminus. The Commission revised its initial formula following Comsat's complaint, though not entirely to the corporation's satisfaction.[32]

And the problem emerged again in each of the requests for authorization of transatlantic cables over the past 15 years. Each time the FCC has ordered a compromise, requiring the purchase of a percentage of overseas circuits by the carriers from Comsat.[33]

A critical part of the problem, of course, has been that Comsat was restricted to operating as a "carriers carrier." In August, 1982, the FCC released Comsat from that restriction.[34] No longer is Comsat precluded from selling its services directly to end users such as banks or the airlines that are major purchasers of international services. As a result of the decision, Comsat is not limited to selling its services to the IRCs and AT&T, who then market the circuits from Comsat in combination with the circuits available through the cables which the carriers own jointly. Comsat, however, must offer its services to the public through a separate subsidiary to ensure that it does not take unfair advantages of its position in Intelsat.

Central as the contest between satellite and cable has been, however, the decision of the FCC in Docket 16495 had greater impact on the course of Comsat's development.[35] In September 1965, the American Broadcasting Co. petitioned the FCC to be permitted to operate a domestic satellite service primarily for the transmission of television programing. Comsat opposed the application, arguing that the Communications Satellite Act of 1962 granted them exclusive rights to the ownership of satellite facilities and the provision of domestic satellite communications services. In March 1966, the FCC returned ABC's application and opened Docket 16495.

---

[31] Aviation Week & Space Technology, Apr. 18, 1966, p. 28; ibid., May 2, 1966, p. 26.

[32] Aviation Week, Feb. 10, 1969; Business Week, June 20, 1970, p. 30.

[33] ———.

[34] FCC 82-357. Aug. 5, 1982.

[35] 22 FCC 2d 86 (1970); 35 FCC 2d 844 (1972); 38 FCC 2d 665 (1972); for a fuller discussion of docket 16495 and the resulting decisions, see chapter 3 section IX.

Four years later the Commission adopted ABC's original approach, endorsing diversity in the ownership and operation of domestic satellite facilities and services. The FCC decided to "open the skies" to any "non-Federal Government entity, including the Communications Satellite Corporation, other common carriers, and noncarriers, to construct and operate (either individually or jointly) communications satellite facilities for domestic use."

The ambiguity of section 701(d) of the 1962 act and the original international perception of Comsat's mission, coupled with the evolution of satellite technology, led to Comsat being only one participant among many in the most lucrative satellite communications market in the world. The monopoly the company enjoyed internationally was not to be paralleled in the United States, however much it believed that the intent of Congress had been otherwise.

While several restrictions were placed on Comsat in the Commission's Second Report and Order in Docket 16495, most were lifted on reconsideration later that same year (1972).[36] But even on relatively equal footing with other carriers, Comsat did not dominate the domestic communications "land rush" that followed the 1972 decisions. The company had argued that its unique experience in the management of "space-segment" communications made it better able to serve the public's needs and the candidate for exclusive authority to provide domestic satellite services. Some Commissioners were convinced by at least part of that argument.[37] But, whatever technical superiority and experience Comsat may have had, it did not dominate the domestic market. Of the almost twenty satellites in operation, Comsat has only four. All are leased entirely to AT&T and GTE, the two major domestic common carriers, primarily for voice traffic.

Responding to the guidelines set forth in the FCC's Domestic Satellite orders, Comsat created a wholly owned subsidiary—Comsat General—to launch, own, and operate the Comstar series of domestic satellites. While the capacity is currently leased to other carriers, the Commission has ruled that this relationship must end when the current Comstar series expires because of Comsat General's participation with IBM and Aetna Life and Casualty in Satellite Business Systems (SBS)—a venture which will be in direct competition with the carriers now leasing the Comstars' capacity.

SBS is the successor to CML Satellite Corp., the consortium formed between Comsat, MCI, and Lockheed that was mentioned prominently in the Commission's Domestic Satellite proceeding. SBS began with an attempt by IBM and Comsat General to form a partnership and create a new, sophisticated business satellite service based on rights to be purchased from MCI and Lockheed. The FCC balked; but, the Commission suggested that such a plan might be acceptable if IBM and Comsat were to find a third partner and assure that the new partner had at least a 10 percent ownership interest in the venture.[38] The Commission also limited the ownership of either of the other partners to 49 percent or less. Southern Pacific Communications, Western Union International and others were considered and rejected as third partners. In late 1975 Aetna was selected; on December 22 the partners filed an application under which SBS would operate a satellite system providing domestic switched digital service between various points of its private line subscribers. The Commission approved.[39] The Department of Justice, Western Union, and American Satellite Corp. appealed the decision, and lost.[40] In 1980, SBS began to launch its satellite fleet.

---

[36] 35 FCC 2d 844; 38 FCC 2d 665.

[37] See dissent of Chairman Burch in which Commission Reid and Wiley joined, 35 FCC 2d 844, 862 (1972).

[38] CML Satellite Corp., 51 FCC 2d 14 (1975).

This review of the origin of SBS raises the question: what is the current structure of Comsat? It began as a single integrated company. Today, with Comsat General, its SBS joint venture, and other subsidiary activities, it is now more than that.

2. *Current structure of Comsat*

Today the parent Comsat provides satellite facilities and services directly which it is required to provide under the Communications Satellite Act of 1962 (so-called "jurisdictional services"). Comsat provides other satellite transmission services (so-called "nonjurisdictional services") through its Comsat General subsidiary. A variety of other communications products and information services are produced by a series of subsidiaries, including Comsat General.[41]

Jurisdictional services include communications satellite facilities and transmission services provided by Comsat through the system of the International Telecommunications Satellite Organization (Intelsat) and the system operated by the International Maritime Satellite Organization (Inmarsat). Inmarsat is a relatively new organization, established in 1979. Comsat's functions for it were outlined in 1978 amendments to the Communications Satellite Act which will be discussed below.

Nonjurisdictional services includes all other communications satellite facilities and transmission services provided by Comsat. All such services are currently provided by Comsat General through the Comstar and Marisat systems.

Communications equipment is manufactured and marketed by Comsat General Telesystems, a wholly owned subsidiary of Comsat General. Computer-aided design, manufacturing the test products and services are provided by Comsat General Integrated Systems (CGIS), a second wholly owned subsidiary of Comsat General. A planned satellite-to-home subscription television service will be offered by Satellite Television Corp. (STC), a wholly owned subsidiary of Comsat. Environmental information services are produced by Environmental Research and Technology (ERT), a wholly owned subsidiary of Comsat.

Comsat thus has three subsidiaries and two subsidiaries of those subsidiaries. Comsat, through Comsat General, also holds a one-third interest in SBS. The following provides an overview of the services offered by Comsat.

---

[39] Satellite Business Systems, 62 FCC 2d 997, reconsideration denied, 64 FCC 2d 872 (1977).

[40] *U.S.* v. *Federal Communications Commission*, 652 F. 2d 72 (D.C. Cir., 1980).

[41] The information for this section is drawn from the FCC's Comsat study, final report and order, May 1, 1980, common carrier docket No. 79-266; public filings by Comsat in that proceeding; and, Comsat's most recently filed SEC form 10-K.

a. Intelsat services.—Through its World Systems Division, Comsat provides communications satellite services, using the facilities of the Intelsat global system, between the United States and other countries and, to a limited extent, between the continental United States and offshore U.S. points.

Virtually all of the services provided by Comsat through Intelsat are used by authorized U.S. international common carriers. The principal users are AT&T (72 percent), RCA Global Communications (3.9 percent), ITT World Communications (3.8 percent), and Western Union International (2.9 percent). Previously, FCC policy permitted Comsat to provide services (other than transmission of television signals) directly to noncarrier users only in unique and exceptional circumstances. The recent FCC decision discussed above now allows Comsat to provide services directly to end customers.[42]

Users of international television transmission services may obtain those services directly from Comsat rather than through the common carriers. Comsat filed a tariff for this service in June 1980 and provided service under it in 1980.

Intelsat operates under definitive agreements which became effective in 1973. They replaced interim agreements under which Intelsat had been established in 1964. Intelsat has 106 member countries. To become a member of Intelsat, a government accedes to the Agreement Among Governments and it, or its designated telecommunications entity (signatory), signs the Operating Agreement. Comsat is the U.S. signatory to the Operating Agreement. (See section III for an indepth review of Intelsat.)

In general, each signatory has an investment share in the Intelsat system equal to its use of Intelsat satellite facilities (the "space segment"). Comsat's use of the space segment is determined in large part by the extent to which the U.S. international common carriers, which own undersea cables, route communications through the Intelsat system. The FCC regulates the distribution of traffic between satellites and cables and seeks to assure equitable distribution. Comsat's relative use of the space segment is also affected by the growth of other signatories' use of the space segment.

Intelsat currently provides service in the Atlantic, Pacific, and Indian Ocean Regions through satellites of the Intelsat IV, IV-A, and V series. Ford Aerospace, a subsidiary of the Ford Motor Co., is constructing the Intelsat V series of satellites which are currently being launched. Another American firm, Hughes, has been selected to produce the next series of communications satellites, Intelsat VI.

To date, all of Intelsat's satellites have been manufactured by U.S. companies and launched by the National Aeronautics and Space Administration (NASA). Intelsat reimburses NASA for the costs of each launch. Several of the Intelsat V satellites, are scheduled to be launched by Ariane vehicles under contract with the European Space Agency.

b. Inmarsat services.—Beginning in 1982, Comsat now provides commercial maritime satellite services through a global system operated by Inmarsat. Inmarsat came into existance through international agreement in July 1979. Inmarsat's structure is essentially similar to Intelsat's.

---

[42] See note 34 above (FCC 82-357. Aug. 5, 1982) and accompanying text.

Pursuant to a 1978 amendment to the Communications Satellite Act, Comsat is the designated U.S. signatory to Inmarsat. As a result, Comsat has a financial interest in Inmarsat facilities similar to its interest in Intelsat. Under the 1978 amendments, Comsat is not limited to serving other carriers, but will be able to offer services directly to end users. The 1978 amendment also provided for a system of governmental supervision and regulation of Comsat's participation in Inmarsat as the U.S. signatory—the so-called "instructional process."

At its November 1980 meeting, the Inmarsat Council approved the negotiation of contracts with three entities for the lease of satellite facilities in order to begin operation in early 1982: (1) the lease from Intelsat of capacity in three Intelsat V satellites; (2) the lease from the European Space Agency of two satellites; and (3) the lease from Comsat General, acting for the Marisat joint venture, of capacity on the Pacific Region Marisat Satellite.

The FCC Comsat Report discussed without any recommendation the question of the financial integration of Comsat's Intelsat and Inmarsat activities.[43] Comsat argues that given the high expenditures required for the establishment of the Inmarsat system, it is uncertain when the services provided through Inmarsat will contribute to the company's profits. In 1980, the Commission began a rulemaking proceeding which sought comment on alternative approaches to Comsat's recovery of Inmarsat losses during the initial period of operation. Comsat proposed that it be allowed to combine for ratemaking purposes its Inmarsat net expenses with its Intelsat revenue requirements. Recently the FCC concluded that proceeding and issued an order denying the Comsat proposal.[44] At the same time the FCC also adopted a policy allowing persons other than those at Comsat to own share stations accessing Inmarsat in the future if it is shown to be in the public interest.

c. Research and development.—Comsat conducts an extensive research and development program intended to improve communications satellite technology. Under contract, the corporation performs certain aspects of Intelsat's research and development program. Comsat also conducts research and development for SBS under contract.

d. Comstar and Marisat services.—The Comstar program and its gradual phase out as a result of the SBS venture were outlined earlier. Marisat is a companion Comsat General program. Marisat provides communications services to the U.S. Navy and to the commercial shipping and offshore industries, such as fishing and oil exploration.

Under a joint venture agreement with three other U.S. international carriers, Comsat General has an 86 percent interest in the Marisat facilities and serves as manager for the joint venture. Since 1976, the Marisat system has offered telephone, telex, facsimile, and data communications services to an increasing number of commercial maritime users. At the beginning of 1981, over 500 ships and offshore drilling rigs were equipped with Marisat shipboard terminals.

---

[43] Final report and order, FCC 80-218, Apr. 22, 1980.

[44] FCC 82-375, Aug. 5, 1982.

Commercial maritime services are now provided by Comsat through the Inmarsat system. As noted above, Inmarsat negotiated with Comsat General and leased commercial Marisat satellite capacity for the first years of Inmarsat operation.

e. Satellite Television Corp. [STC].—STC is one of eight applicants being considered by the FCC for the operation of direct broadcast satellite (DBS) services to the continental United States. STC proposes to provide three channels of programing directly to homes across the country. The service would employ four satellites to cover the Nation, one each for a geographic area roughly corresponding to each of the Nation's time zones.

f. Manufacturing.—Since 1979, Comsat General Telesystems has been manufacturing echo cancelers and other specialized telecommunications products, such as time division multiple access equipment. TeleSystems is developing other signal processing equipment and Earth station components and subsystems. In late 1980, TeleSystems assumed responsibility from Comsat General for the marketing and maintenance of Marisat equipment.

g. Integrated design and manufacturing systems.—CGIS is developing integrated design and manufacturing systems consisting of hardware and software for integrated computer-aided design, manufacturing, and testing of digital and microwave communications equipment. In 1980 CGIS acquired Compact Engineering, a supplier of computer-aided design software. In 1980 Comsat General acquired a minority interest in Ungermann Bass, a supplier of a general purpose communications network system that connects data and word processing equipment within a local area. In 1981 CGIS acquired Comprehensive Computing Systems and Services, a supplier of computer-aided design software.

h. Environmental information services.—Environmental Research and Technology, Inc. (ERT) was acquired by Comsat in 1979. ERT provides a full range of environmental information services to both commercial and governmental users worldwide. ERT offers environmental monitoring, analysis and prediction systems. ERT also provides services in related areas such as ship routing and other marine information. Under a contract with the United States Government, ERT has worked to develop computer software for use with meteorological satellite systems.

i. Satellite business systems.—SBS intends to establish a U.S. domestic satellite system providing intracompany communications network for businesses and other organizations which have large-volume communications requirements among dispersed facilities. The networks are fully switchable and offer users a full range of communications services—voice, high-speed data, high-speed facsimile, and teleconferencing—all in digital format. The marketing push has been for those companies whose telephone expenditures run more than $300,000 per month.

The cost of the entire system is estimated at roughly $500 million. Comsat's share is approximately $175 million. Users will include Boeing Computer Services, General Motors, Travelers Insurance, Wells Fargo Bank, Westinghouse, and Sears. Service areas could include Canada, Mexico, and portions of Europe. Agreements have already been reached which may facilitate entry into Canada.

The SBS system is the first domestic Ku band (14/11 GHz) satellite service. Operation at frequencies that high poses far less threat of interference with terrestrial microwave facilites, permitting greater penetration into major metropolitan markets. In addition, smaller facilities can be used on the ground for Ku band. Estimates suggest the $1,000 of receive-only equipment in the Ku band will serve as well as $10,000 to $20,000 worth in C band. Two of the SBS satellites have been launched and the company is already in limited operation.

3. Future directions: The FCC Comsat study

The legislation which carved out Comsat's role in Inmarsat, amending the Communications Satellite Act in 1978, also required the Federal Communications Commission to conduct a study, then report to the Congress, regarding Comsat's corporate structure and operating activities.[45] The assigned task was to determine whether any changes were required to insure that Comsat is able to fulfill its obligations effectively and carry out its functions under the Communications Satellite Act of 1962. The Commission opened a formal inquiry on October 19, 1979.[46]

On May 1, 1980, the FCC issued its final report and order and transmitted it to Congress.[47] The report made several recommendations to the Congress and announced the Commission's intention to initiate a rulemaking proceeding to determine the proper structure for the corporation. The legislative recommendations included a proposal to clarify Comsat's authority to engage in activities not inconsistent with its statutory obligations. The report also recommended that the statutory instructional process applied to Comsat in their Inmarsat activities be applied to Intelsat as well. Issues presented to the Congress without recommendations included prominently the financial integration of Comsat's Intelsat and Inmarsat activities. The Commission also raised the question of whether a U.S. Government representative should attend Intelsat and Inmarsat meetings to assure that Comsat was following its instructions from the Government.

The rulemaking announced with the report was designed to consider whether the jurisdictional services provided to Intelsat and Inmarsat should be separated from all other lines of business by placing them in the parent corporation and placing all other activities, including Comsat laboratories, in a separate subsidiary. The FCC stated that it believed that such separation would be necessary to reduce the opportunity for cross-subsidization, to prevent conflicts of interest and to avoid situations in which Comsat would have an unfair advantage over its competitors because of its jurisdictional activities.

The report received mixed reviews. Comsat's potential (and, in a few areas, actual) competitors objected that the Commission proposals for restructuring did not go far enough. Western Union International argued that the Commission should not foster the expansion of Comsat's role in any way, because "any expansion of Comsat's activities would contravene sound public policy. The unique monopolistic role accorded to Comsat precisely to enable it to carry out its statutory missions would, if carried into regulated or unregulated markets, destroy full and fair competition, financially cripple private sector competitors, and lead to higher charges and less efficient and innovative services, all to the public detriment." [48] RCA Globcom said that if Comsat "is authorized to serve end users directly, none of the proposed changes in Comsat's structure or operations would offer the slightest deterrent to Comsat's using its Intelsat monopoly to engage in anticompetitive activity and cross-subsidization."[49] Both the Department of Defense and the Department of State raised serious questions about the limitations on the ability of the portion of Comsat providing regulated, jurisdictional services to offer to the Government the full range of facilities and services needed in the most efficient and economical package. State also suggested that the proposals regarding public access to Intelsat documents be left to the agencies under whose jurisdiction they would be maintained within the limits of current law—the Freedom of Information Act.[50]

---

[45] 47 U.S.C. 751.

[46] Implementation of Inmarsat, 47 FCC 2d 59 (1979).

[47] Final report and order (Comsat study), FCC 80-218, Apr. 22, 1980.

Comsat responded to the Commission report with an internal reorganization that took into account the recommendations, as well as other factors. In comments on the proposed rulemaking to reorganize its structure, Comsat indicated that it had no disagreement with the goals of the rulemaking. The company endorsed the principle that ratepayers should bear only those costs legitimately incurred in their behalf and that fair conditions must be maintained in competitive markets. Comsat argued, however, that since it had become involved in activities outside of its jurisdictional responsibilities, it had taken appropriate steps to prevent improper cross-subsidization. In addition, Comsat suggested that rather than exploiting its unique position in the international satellite organizations to its competitive advantage, it made Intelsat/Inmarsat originated documents publicly available as fully and quickly as possible. Furthermore, Comsat flatly stated that licenses to technical documents and patented inventions resulting from activities charged to the ratepayer were made available to financially qualified applicants on fair and nondiscriminatory terms.

Its internal reorganization was Comsat's response to the FCC report and rulemaking. The major structural change involved the establishment of Comsat World Systems Division [WSD], solely responsible for Intelsat and Inmarsat activities. WSD created a discrete cost center for the Corporation's monopoly operations and allowed regulation of these activities to be confined in a separate, clearly defined segment of the Corporation. WSD was structured in an attempt to assure the greatest practicable separation: virtually all of the personnel responsible for the Division's daily operations perform those activities on a full-time basis and are not involved in any of the decisionmaking processes of Comsat's other endeavors.

---

[48] Telecommunications reports, Jan. 19, 1981.
[49] Ibid., Jan. 26, 1981.
[50] Ibid.

Similarly, the Comsat subsidiaries have no decisional impact on WSD's monopoly activities.

D. ISSUES

The critical issues of most immediate importance to Congress are those raised by the Federal Communications Commission in the Comsat study discussed in the previous section. Rather than repeat the discussion of those pages, this section simply outlines briefly the questions raised and in need of resolution.

1. Should the Communications Satellite Act be amended to redefine the scope of what businesses Comsat is permitted to engage in, allowing Comsat to diversify into areas clearly beyond satellite communications?
2. Should Comsat be divided into a parent and a fully separated subsidiary; the parent providing monopoly [Intelsat/Inmarsat] services and the subsidiary carrying on all other ventures?
3. What role should the FCC play in policing any legislatively mandated structural changes such as that outlined above?
4. Should more direct Government control of Comsat's representation of the United States in the international satellite organizations be established?
    1. By requiring in statute the same instructional process of Intelsat as exists for Inmarsat?
    2. By placing a "watchdog" Government representative at Intelsat and Inmarsat meetings to assure that Comsat adheres to the instructions given it?
5. Should the Congress assess, independently, the questions of the allocation process between satellites and cable facilities?
6. How should the United States respond to the end of its monopoly on the launch and provision of satellite facilities—to Intelsat, to any other systems or carriers? Should Comsat be instructed by the FCC, the executive branch or the Congress if any response is developed?

To date, as noted earlier, the United States has supplied all the satellites and all the launch facilities for the international satellite systems. The Europeans, Japanese, and Chinese now have an independent launch and satellite production capability.

III. INTERNATIONAL TELECOMMUNICATIONS SATELLITE ORGANIZATION (INTELSAT)

The International Telecommunications Satellite Organization [Intelsat] was created to establish and maintain a global commercial telecommunications satellite system. It represents the first attempt to exploit space technology on an international basis. Intelsat emerged from the initiatives of the United States, which had been fostered by President John F. Kennedy, and designed to promote the availability of reliable satellite communications worldwide. The United States emphasized that such a satellite system should be both peaceful and global in nature, but also that it should be commercially viable and technologically efficient. Today 107 nations are members of the Intelsat system, but an examination of Intelsat's history and operations serves to identify the original U.S. goals for space technology. It also illustrates the key play-ers in international satellite communications. Beginning with the establishment of the Communications Satellite Corporation [Comsat] in the Communications Satellite Act of 1962 and concluding with current policy dilemmas this chapter will highlight the technological developments and U.S. positions which are effecting the international satellite system generally and Intelsat in particular.

A. ORGANIZATIONAL HISTORY AND EVOLUTION

The formation of Intelsat began with the creation of the Communications Satellite Corporation [Comsat] in 1962.

1. Communications Satellite Act of 1962

Experiments with Echo, Telstar, and other early communications satellites indicated their commercial promise and led to discussions in the U.S. Congress on the institutional and financial framework in which the new technology would develop. Alternative proposals for three different types of systems were considered: a government-owned corporation, an all-private corporation dominated by the U.S. overseas carriers, and a hybrid corporation with ownership to be shared by private investors, the U.S. overseas communications carriers, and the U.S. Government. The hybrid proposal was adopted and the 1962 Communications Satellite Act created the Communications Satellite Corporation [Comsat]. (See chapter three, section II for an indepth review of the establishment of Comsat). Ownership was divided between the public at large and the major U.S. overseas carriers: appointment of several members of the board of directors was made by the U.S. President; and controls and regulatory powers over Comsat by the Federal Communications Commission [FCC] and the Department of State were established.

2. Formation of Intelsat

Shortly after its formation, Comsat officials and appropriate U.S. Government agencies, acting under a congressional mandate to establish an international communications satellite system, began negotiations for the establishment of an international organization to develop and manage a global commercial communications network. As a result of several years of international negotiation, the agreements establishing interim arrangements for a global commercial satellite system entered into force August 20, 1964. Intelsat was to operate under the interim arrangements for 5 years, after which definitive agreements would be negotiated.

3. Interim agreements

There were two interim agreements negotiated: an agreement among governments establishing interim arrangements for a global commercial communications satellite system, and a special agreement, signed by the designated communications entities of each nation, setting up the mechanics to execute the interim arrangements.[51]

---

[51] Most European communications carriers are governmental or quasi-governmental entities. the difference in Comsat's role as a private profit entity prompted the other nations to insist on some agreement to which the U.S. Government, not its communications entity would be a party. Hence, the signing of one agreement by governments and another by communications entities.

The agreements established that Intelsat was to be governed by the Interim Communications Satellite Committee [ICSC]. The ICSC was the policymaking body for Intelsat and was responsible for establishing and operating the "space segment" of the system. Voting in the committee corresponded to the degree of ownership. Ownership had been apportioned according to the projected use of the system. For example, the United States had 61 percent of the votes. Comsat was designated as manager, responsible for the design, development, construction, establishment, operation, and maintenance of the space segment.

The desire by other nations to play a greater role in Intelsat grew and some members of the Intelsat system sought to decrease the dominant position of the United States in the Intelsat organization. After numerous ICSC meetings, recommendations were made for the Intelsat definitive arrangements in 1968. The Plentipotentiary Conference on Definitive Arrangements for the International Telecommunications Satellite Consortium began in 1969, and continued meeting periodically until 1971. By May 1971, the proposed permanent agreements were open for signature. They entered into force in February 1973, forming the basis of Intelsat's present structure and operation.

4. *Definitive agreements*

The definitive agreements more clearly outlined Intelsat's legal standing as an international intergovernmental organization, clarified its authority to provide domestic as well as international telecommunications services, and created procedures to ensure that member countries not establish separate, competing satellite systems. [52]

Most importantly, the definitive agreements led to a significant reorganization of Intelsat which underlies the current structure. U.S. power within Intelsat was diminished by the reorganization making the present Intelsat organization broader and more representative of views of the smaller nations.

Intelsat is a four part structure, including a Board of Governors, Assembly of Parties, Meeting Signatories, and the Executive Organ. The principal decisionmaking entity is the Board of Governors which replaced the ICSC. It makes recommendations for the design, development, construction, establishment, operation, and maintenance of the Intelsat space segment. Voting is based on ownership quotas, although no country is allowed more than 40 percent of the vote. In addition, the United States relinquished the unilateral veto power which it held in the ICSC under the interim arrangements.

The Assembly of Parties is composed of governments which are parties to the Agreement, and considers those aspects of Intelsat that are primarily of interest to the parties as sovereign States. It is empowered to formulate policies and long-term objectives consistent with the principles, purposes, and scope of Intelsat activities. Each party has one vote, thereby increasing the influence of the smaller users (usually the developing nations) in setting policy.

---

[52] Pelton, Joseph N. Intelsat, in the 1980's. Inteltrade, vol. 2, No. 21, p. 10.

The Meeting of Signatories considers primarily matters relating to the financial, technical, and operational aspects of the system. Among the various responsibilities, the meeting of Signatories considers and decides upon any recommendation for an increase in the capital investment ceiling, and establishes rules for the approval of Earth stations for access to the Intelsat space segment, the allotment of Intelsat space segment capacity, and the establishment and adjustment of the rates of charge for space segment utilization. Each party has one vote.

These changes in the Intelsat structure provided all parties with a forum in which to contribute ideas and participate in the general formulation of policy for the organization.

The final element is the Executive Organ, originally headed by a Secretary General from 1974–1976 and now headed by a Director General, Mr. S. Astrain. This individual is the chief executive officer and legal representative of Intelsat and is responsible to the Board of Governors for the performance of all management functions.

The role of systems manager remains a very influential one. Between 1973 and 1979 Comsat functioned under a 6-year "management services contract" with specified technical and operational functions. During the final 2 years of that contract most of the planning and operational duties gradually were transferred from Comsat to Intelsat's Executive Organ culminating in a new Permanent Management Agreement. Under this arrangement, for example, Intelsat now manages the space procurement process and the Director General is in charge of day-to-day planning and operations. Intelsat also explores a wide spectrum of new telecommunication services and the technology necessary to support such services on an ongoing basis.

Comsat however, continues to play a pivotal role in Intelsat's operations. It provides certain technical services to Intelsat under two contracts, one covering a 4 year period and the other 6 years. Included in the 6 year contract are such things as technical support in the spacecraft manufacturing process, operating the satellite control center, monitoring satellite positioning, and in-orbit testing, and negotiations for launch services. The 4 year contract focuses on technical support for future spacecraft proposals and procurement.

B. TECHNOLOGY [53]

1. Spacecraft

Intelsat has launched six different series of satellites. The first, Intelsat I consisted of one satellite which was placed in orbit in 1965. It provided a capacity of 249 circuits, or one television channel, across the Atlantic and could connect only two Earth stations at a time. Intelsat II satellites were first launched in 1966 and provided capacity equal to that of Intelsat I. However, they offered multidestination reception by receiving Earth stations. A principal purpose of this series was to provide support to NASA for the Apollo lunar exploration program. The Intelsat III series, with an intitial launch in 1968, inaugurated the first truly global coverage, with satellites over the Atlantic, Pacific, and Indian Ocean regions.

---

[53] Technical information provided by Intelsat and NASA.

Intelsat IV satellites, first launched in 1971, averaged 4,000 circuits and two television channels. They offer the option of spotbeam usage, by means of which narrow beams of high power are focused onto small areas of the Earth's surface, as well as the usual global beams which cover larger areas at lower levels. Intelsat IV-A satellites provide a demand access system which allows the flexible interconnection of small traffic streams upon demand. This demand assignment system provides greater efficiency in the utilization of the satellites, as well as the ability to connect small traffic routes which would not be economically viable with dedicated circuits. The Intelsat IV-A series also furnishes a higher capacity 6,250 circuits and two television channels.

All present Intelsat satellites operate in synchronous equatorial orbits, which make possible 24-hour continuous reception and transmission with minimal tracking by ground stations. The Intelsat IV and IV-A satellites receive signals transmitted from the ground on frequences in the 6 GHz band and retransmit them to the ground on frequencies in the 4 GHz band.

FIGURE 3-1

OVERVIEW OF INTELSAT SATELLITE GENERATIONS

Satellite	Ckt-Yrs. per Spacecraft 1/	Capital Cost per Ckt-Year	Capital Cost per Ckt-Yr. in 1965 $	Notes on Technology
INTELSAT I (1965 launch)	360	$32,500	$32,500	World's first commercial satellite
INTELSAT II (1967 launch)	720	11,400	10,700	Introduced multi-point capability
INTELSAT III (1968 launch)	6,000	2,000	1,800	Simultaneous forms of communication (e.g., telephone, TV, Telex)
INTELSAT IV (1971 launch)	28,000	1,200	900	Introduced spot beam concept
INTELSAT IV-A (1976 launch)	42,000	1,100	600	Multiple use of same frequency bands
INTELSAT V (1981 launch)	84,000	850	300	Use of new frequency bands plus reuse of frequencies

1/Spacecraft design life times circuit capacity.

Source: COMSAT

Prior to the Intelsat V series, all Intelsats (fig. 1) were spin stabilized so that they maintain their orientation in space by means of a rotation of the body of the satellite along an axis parallel to the Earth's axis. All have been powered by arrays of cilicon solar cells mounted on the spinning body.

The satellite body serves as a platform for the communications payload, which includes the receivers, amplifiers, transmitters, and antennas. The payload is "despun" to maintain its Earth orientation. The rotating outer structure carries with it the electric power system, the stabilization system (including its fuel tanks) and a solid-fuel rocket engine to provide the necessary "kick" at the apogee of the satellite's transfer orbit to place it in a circular equatorial orbit with virtually zero inclination.

The stabilization system depends on infrared sensors to determine the direction of the Earth, and on small thrusters to align the satellite spin axis properly and keep the antenna beams pointed toward the Earth. The thrusters, which are fueled by hydrazine gas, generate the reaction force necessary to adjust the satellite's position. With them the stabilization system can control the attitude of the spin axis, move the satellite in the east-west direction and counteract the gravitational influence of the Sun and Moon, which tends to affect the inclination of the satellite. This correction for inclination consumes a major fraction of the hydrazine fuel and is therefore closely related to the effective life expectancy of the satellite.

Monitoring the condition of the various satellite systems is accomplished through telemetry in which a variety of sensors detect temperature, voltages, and other conditions, and transmit them to Earth stations through a radio link. This information is subsequently sent to the control center, where it is processed for evaluation. If any malfunction is detected, corrective action can be taken by radio command from the same stations.

The Intelsat V series, introduced in 1980, differs from previous satellites in a variety of ways. These satellites are three-axis stabilized rather than spin stabilized. They have an increased capacity of 12,000 circuits, twice that of the Intelsat IV–A series. They are also designed to make more efficient use of the 4 GHz and 6 GHz bands through polarization discrimination. On each frequency two signals can be transmitted, one set circularly polarized in the left-hand sense and the other set circularly polarized in the right-hand sense, thereby providing double utilization of frequencies in each geographical area. In addition, unlike earlier satellites, the Intelsat V series operates in the 14/11 GHz bands as well as the 6/4 GHz bands. The 14/11 GHz frequencies are used twice through east and west spot beams. There are six communications antennas on the Intelsat V satellites which include two global coverage horns, two hemispherical/zone offset-fed reflectors and two offset-fed spot beam reflectors. The design life of the satellite is seven years.

The first Intelsat V of a projected series of at least 12 Intelsat V and V–A satellites was launched in December 1980. Two other Intelsat Vs are now also in service over the Atlantic Ocean Region. A second group of Intelsat V satellites (F–5 to F–9), will provide a maritime service capacity in addition to the previously described features. The maritime communications subsystem provides the equivalent of 30 full-time voice circuits to ship terminals that make use of the Marisat system. (See section VI for description of the Marisat system.) As presently designed, Intelsat will lease this capacity to Inmarsat. Unlike earlier Intelsat V spacecraft which used the Atlas Centaur vehicle provide by NASA, the F-6 to F-8 satellites will be launched by Ariane vehicles under contract with the European Space Agency. These launches will be the first to use non-U.S. vehicles.

The third group of Intelsat V satellites, the F-10 to F-12 spacecraft, is referred to as the Intelsat V-A program and is expected to begin in 1984. These spacecraft additionally will have two steerable spot beams operating in the 6/4 GHz frequency band. The Intelsat V-A satellites also will be capable of reusing the frequency band by means of dual polarization. The Intelsat V-A series will not provide maritime communications services.

The Intelsat VI series satellites will have the capacity for at least 30,000 two-way telephone circuits and four television channels and are designed to be launched either by the NASA space shuttle or Ariane 4. This series of satellites is planned to provide enhanced capabilities for supporting regional and domestic services. These spacecraft are designed to reuse six-fold frequencies in the 6/4 GHz band and two-fold the frequencies in the 14/11 GHz band. Each satellite will carry 38 transponders in the 6/4 GHz band and ten transponders in the 14/11 GHz band. Additionally, they will make use of Satellite Switched Time Division Multiple Access [SS/TDMA] to allow for inter-connectivity among various beams and to increase the satellites' overall traffic capacity significantly. The Intelsat VI series is expected to commence operation in the mid-1980's and will be capable of being reconfigured to operate in the Atlantic, Pacific, and Indian Ocean regions as needed. Intelsat recently announced its decision to contract with Hughes Aircraft for the supply of Intelsat VI satellites.

2. Earth stations

Earth stations in the Intelsat system are owned by the individual nations or their designated supplier of communications services. They are therefore tailored to the needs of individual operators, although their technical performance is specified by Intelsat. These stations can simultaneously process all forms of communications signals—i.e. telephone call, telegraph messages, high-speed data, facsimile and television signals. System flexibility permits instantaneous direct communication between one station and another or among many stations at the same time.

There are three types of standard earth station antennas. They are:

Standard A: The oldest and most widely used system typically uses a large parabolic antenna 30 meters (105 feet) in diameter. The entire antenna structure is mounted on wheels and can be rotated on a track 50 feet in diameter atop a pedestal. The 12 story tall antenna structure can be rotated to precisely track a satellite stationed 22,240 miles altitude to within 0.02 degree accuracy. Signals received from the satellite (4 GHz) are focused by the antenna, funneled into high sensitive receiver amplifiers, boosted in power again, then further processed through the station for dissemination through coaxial cable and microwave link. Outgoing signals to the satellite are transmitted simultaneously but at a different frequency (6 GHz).

Standard B: These smaller antennas (33–39 feet) are used mainly by countries with limited telecommunications requirements. Some nations use a Standard B station as an initial entry into the Intelsat system and later upgrade their systems to include the Standard A antenna as their communications needs become more demanding. Although the lower capacity stations are less expensive in terms of capital investment, the circuit costs are higher.

Standard C: This newest station antenna is 55–62 feet in diameter and is designed to operate in the 14/11 GHz bands with the Intelsat V series satellites.

C. Operation and Economics

During the first year of Intelsat operation, 1965, one satellite and five earth stations were operating in the Atlantic region, carrying 65 two-way circuits. Since the satellite had no multiple-access capability, only one path could be served, that is, only two earth stations would be connected, one in North America and one in Europe. Earth stations in Germany, France, and United Kingdom alternated carrying satellite traffic from Europe on a weekly basis. A station in Italy was assigned the weekend traffic.

1. Technological evolution and system expansion

In over 15 years, there have been numerous technological improvements and the system has expanded substantially. (See Figure 2) Intelsat's global satellite system can be divided into two segments: (1) space, which involves the satellite portion of the system and (2) ground, which includes the Earth stations. As of March 31, 1982, the space segment contained 16 satellites (including spare and contingency spacecraft) operating in synchronous orbit at an altitude of 22,240 miles. These satellites are a combination of Intelsat IV, IV–A, and V spacecraft operating over the Atlantic, Pacific, and Indian Ocean Regions. The satellites provide multiple access so that all earth stations can operate simultaneously.

FIGURE 3-2

YEAR-BY-YEAR HISTORY OF INTELSAT DEVELOPMENT

(1965–1971)	'65	'66	'67	'68	'69	'70	'71
Total number of countries territories or possessions served by INTELSAT (directly & indirectly)	15	15	22	25	52	60	77
Number of Earth station-to-earth station pathways	1	1	10	19	82	131	181
Total number of half circuits	150	172	688	1,142	2,835	4,259	5,822
Hours of television	80	152	450	1,372	1,826	2,428	3,562
SPADE usage (billable minutes)	—	—	—	—	—	—	
Circuit restoration (half circuit days)	36	598	2,284	7,428	14,722	19,005	20,822
Earth station-to-earth station continuity of service	—	—	—	—	—	—	—
Total system capacity (voice circuits plus television. SPADE capacity not included)	240 or 1 TV	240 or 1 TV	480 or 2 TV	2,400 plus 4 TV	3,600 plus 6 TV	4,800 plus 8 TV	10,400 plus 8 TV
Number of countries leasing capacity for domestic services	—	—	—	—	—	—	—
Annual space segment utilization charge ($US)	32,000	20,000	20,000	20,000	20,000	20,000	15,000
Net investment in INTELSAT space segment ($US 000)	—	—	69,263	85,792	122,498	191,497	232,122

(1972–1976)	'72	'73	'74	'75	'76
Total number of countries territories or possessions served by INTELSAT (directly & indirectly)	93	100	107	107	115
Number of Earth station-to-earth station pathways	255	293	359	406	491
Total number of half circuits	7,497	9,814	11,507	13,369	16,520
Hours of television	6,792	6,817	7,361	7,887	12,952
SPADE usage (billable minutes)	—	135,330	3,439,375	5,711,539	16,235,239
Circuit restoration (half circuit days)	36,428	39,866	41,888	23,060	17,352
Earth station-to-earth station continuity of service	99.870%	99.875%	99.888%	99.892%	99.876%
Total system capacity (voice circuits plus television. SPADE capacity not included)	16,000 plus 8 TV	16,000 plus 8 TV	16,000 plus 8 TV	16,000 plus 8 TV	20,000 plus 8 TV
Number of countries leasing capacity for domestic services	—	—	2	4	6
Annual space segment utilization charge ($US)	12,960	11,160	9,000	8,460	8,280
Net investment in INTELSAT space segment ($US 000)	235,901	258,049	291,358	334,950	351,618

(1977–1981)	'77	'78	'79	'80	'81
Total number of countries territories or possessions served by INTELSAT (directly & indirectly)	122	132	141	154	160
Number of Earth station-to-earth station pathways	558	646	757	840	976
Total number of half circuits	20,199	25,293	32,418	40,615	50,250
Hours of television	15,193	23,293	20,770	28,392	35,658
SPADE usage (billable minutes)	29,879,918	38,453,732	36,306,450	28,010,780	39,333,988
Circuit restoration (half circuit days)	26,254	24,626	55,234	44,924	40,132
Earth station-to-earth station continuity of service	99.904%	99.877%	99.883%	99.893%	99.927%
Total system capacity (voice circuits plus television. SPADE capacity not included)	20,200 plus 8 TV	20,000 plus 10 TV	25,500 plus 10 TV	25,500 plus 10 TV	36,000 plus 10 TV
Number of countries leasing capacity for domestic services					
Annual space segment utilization charge ($US)	7,380	6,840	5,760	5,040	4,680
Net investment in INTELSAT space segment ($US 000)	399,332	436,931	523,462	672,501	852,003

The ground segment consists of 219 international earth station antennas, at 156 sites operating in 136 countries, territories, and possessions. The combined system provides over 1000 earth station to earth station communication pathways. The Intelsat network provides more than 26,000 full-time voice and data circuits, plus the capacity for over 20,000 television transmissions.[54]

Intelsat is presently establishing a new headquarters in northwest Washington, D.C. Contractual agreements were completed in 1980 with John Andrews International Pty., Ltd. of Australia, as the architect of the new structure and preparation of plans and specifications were completed in 1982.

2. System reliability[55]

System reliability has more than tripled since the early 1960s satellites, which typically operated for two years. Today, the life expectancy of Intelsat IV-A and V series satellites is seven years. Continuity of service continues to exceed 99.8 percent for the entire global system.

Monitoring and control of the systems' satellite is the responsibility of Intelsat Spacecraft Technical Control Center in Washington, D.C. Intelsat works through a telemetry, tracking, command and monitoring [TTC&M] network with specialized high performance test antennas that are used to check the satellites just after launching and during transfer orbit. The TTC&M network also tracks the satellites while operating in space.

In addition, a new Communication System Monitor [CSM] consisting of a network of individual monitoring stations located at ten earth stations in the system was recently installed. These stations have automated facilities that measure the performance of communications in all operating satellites and transmit monitoring data to a central computer at the Operation Center at Intelsat Headquarters in Washington, D.C. The CSM system provides state-of-the-art technology for monitoring satellite communications and providing operations management. Through real time observation and analysis of performance trends offered by the system, users can maintain high quality service more effectively.

A related aspect of system reliability is insurance coverage against launch failures. Prior to Intelsat V satellite service such coverage did not exist. With an increased market in this area, Intelsat has been able to negotiate insurance coverage for the first five Intelsat V satellites. The insurance covers launch failure and failure during the first 180 days in orbit.

3. System economics

Since its inception the Intelsat system has attained economic advantages through improved technology and through economies of scale. Although the cost of building and launching satellites has steadily increased, the cost of inflation has been offset by higher communications capacity through longer lifetime and more effective utilization of power and bandwidth. This is reflected in user costs which have decreased drastically since the initiation of service in 1965. For example, beginning in 1982 the charge for a full time unit was reduced by 7.1 percent to a level of $390 a month. When adjusted for inflation, the current rates are more than 15 times lower than they were in 1965.[56]

---

[54] 1982 annual report of Intelsat. International Telecommunications Satellite Organization, Washington, D.C., 1982. p. 8.

[55] Ibid.

Intelsat's capital ceiling was increased to $2,300 million at its 1981 Meeting of Signatories to support the remainder of the Intelsat V program and initiate the Intelsat VI series. Intelsat revenues rose 15 percent in 1981 and this growth rate is expected to continue in 1982 when revenues are projected to reach over $300 million. The cumulative return on member investment since 1973 is 16.1 percent, exceeding the target goal of 14 percent per annum.[57]

D. EARLY POLICY ISSUES [57a]

The formation of Intelsat represented the first significant attempt toward organizing, developing, operating, and regulating a major space technology on a broad international level. The history of Intelsat development provides the background for the various policy issues that have developed and the goals that the United States established in the area of space communications technology.

1. Formation of policy

The formation of the Communications Satellite Corporation [Comsat] set the stage for the development of international space telecommunications. In passing the Communications Satellite Act of 1962 the U.S. Congress determined that communications satellites technology should be exploited commercially, and that a global communications network should be established at the earliest practical date.

> The Congress hereby declares that it is the policy of the United States to establish, in conjunction and in cooperation with other countries, as expeditiously as practicable a commercial communications satellite system, as part of an improved global communications network, which will be responsive to the needs of the United States and other countries, and which will contribute to world peace and understanding.
>
> The new and expanded telecommunications services are to be made available as promptly as possible and are to be extended to provide global coverage at the earliest practicable date.
>
> In order to facilitate this development and to provide for the widest possible participation by private enterprise, the United States participation in the global system shall be in the form of a private corporation, subject to appropriate government regulation.[58]

The United States had thus established its primary goals in the implementation of space communications technology: technical expediency and economic efficiency. Pursuant to the attainment of these goals was the determination that a corporate business entity, motivated primarily by commercial profit and operating efficiency rather than political goals, would develop and implement the technology in the shortest period of time and to the best economic advantage. Thus, the consensus of authorities on the subject is that in the formation of Intelsat, the political goal of broadbased international participation in the new technology was subordinated to the rapid deployment of a commercially viable global communications satellite network. And, by entrusting its continued participation in Intelsat to a business entity, this state of affairs was perpetuated.[59]

---

[56] 1981 annual report of Intelsat. International Telecommunications Satellite Organization, Washington, D.C., 1981. p. 32.

[57] 1982 annual report of Intelsat, p. 31.

[57a] Based upon chapter on Intelsat in "World-Wide Space Activities," House Committee on Science and Technology, Subcommittee on Space Science and Applications, 95th Congress, 2d session, H. Doc. 95-352.

[58] Section 102(a)-(c), Communications Satellite Act of 1962, Public Law 87-624.

The adoption of a commercial philosophy allowed the United States to further another goal, the maintenance of its technological superiority in communications satellite technology. Intelsat procurement on the economic principle of the highest quality for the lowest price assured the U.S. aerospace industry of continued leadership in space technology.

Negotiating from a position of dominance the United States translated these goals—technical and economic efficiency and U.S. leadership in space communications—into the interim agreements which established Intelsat. Specifically, the voting and ownership arrangements reflected the commercial philosophy that a nation should have control of the system in proportion to its usage of the technology, rather than the political goal of widespread participation. In a similar manner, the management of Intelsat and the procurement policy as outlined in the interim agreements strongly favored a dominant role by the United States. Finally, parties to the interim agreements were prohibited from development of commercial satellite systems which would compete with Intelsat.

2. Evaluation of initial U.S. policy

Through Intelsat, a commercially viable global communications satellite network was formed in an expeditious manner. It has operated continuously and reliably since 1964. Thus, in terms of technical and economic efficiency the U.S. policy was a success.

By virtually precluding European technical participation in Intelsat by procurement policies which favored its own aerospace industry, the United States managed to obtain a major share of Intelsat business. Some experts argue, however, that the exclusionary effects of U.S. policies gave Europe the impetus to develop its own space technology capability in order to become independent of the United States and provide services which met its own requirements. The long-range effect may therefore have been to create a more active European space industry to compete with U.S. industries.[60]

Similarly, these early efforts by the United States to dominate Intelsat created resentment on the part of other nations, particularly the Europeans. For example, there was annoyance that European funds were spent on a project destined to maintain U.S. technological superiority in space; that of the revenues invested, there was little or no return in contract funds which would have enabled the Europeans to develop their own space capability; that other nations had a limited voice in the organization; and that specialized needs, such as regional communications systems were not met.[61] It has been argued therefore that U.S. insistence on the maintenance of its own superiority in communications satellite technology did not enhance its relations with other nations, particularly because foreign nations view political participation as an important goal for an international organization such as Intelsat.[62]

---

[59] See: "Intelsat, Policymaker's Dilemma." Judith Tegger Kildow (Lexington, Mass.: Lexington Books, 1973); "International Commercial Satellite Communications. Economic and Political Issues of the First Decade." Marcellus S. Snow (Praeger Publisher: New York, 1976); "Global Communications Satellite Policy." Joseph N. Pelton (Mt. Airy, Md.; Lomond Books, 1974).

[60] See: "Intelsat Policymaker's Dilemma," Judith Legger Killow (Lexington, Mass.: Lexington Books, 1973) and Marcia S. Smith, "The Next Decade in Space: Increase International Economic Competition." CRS Review, July/August, 1982.

This political malaise grew stronger and when the negotiations for definitive agreements began, the Europeans as well as the emerging Third World nations, insisted on a greater role in determining policy for Intelsat, and a diminished U.S. influence in the organization.[63] The structural changes in Intelsat achieved through the definitive agreements and the permanent management agreement reflect this desired shift away from U.S. predominance in Intelsat's management functions. At the same time, use of the Intelsat system by other countries continued to grow. As a result, today the United States has a 24 percent voting share.

E. CURRENT POLICY ISSUES

Advancements in communications technology, changing economic and political realities, and the dynamics of international relations all have altered the environment in which Intelsat was created. Today, European launch facilities compete with those of the United States and regional satellite systems exist. While some of the issues that the United States faced concerning its role in Intelsat remain, they have been recast in the light of new concerns about international telecommunications. At the same time, other issues have emerged reflecting trends in U.S. domestic telecommunications policy and the growing competition in information technology from abroad. The United States' position toward Intelsat hence may be viewed within the broader context of the current debate over U.S. international telecommunications policy.

1. Formulation of U.S. policy

The United States is in a significantly different position compared to other nations when formulating telecommunications policies. In this nation, the private sector is the basic provider of telecommunications services and facilities. This situation has been accentuated in recent years by the substantial effort by Congress and the Federal Communications Commission to promote increasing competition within the U.S. telecommunications industry. Domestically, these efforts are designed to foster the greatest diversity of services at the least possible cost, while maintaining a strong communications network for national defense and universal public service.

This position contrasts with that of most other nations of the world. Although there is some evidence that governments in Western Europe and Japan are opening up elements of their telecommunications activities to the private sector, most telecommunications facilities are either government owned or operated. The fact that international communications involve by their very nature interaction with foreign telecommunication administrations (commonly referred to as PTT's—postal, telegraph, and telephone) defines the parameters of policymaking in this area. International satellite communications involve operating through Intelsat, while cable communications depend upon facilities which are jointly owned by U.S. telecommunications common carriers and foreign PTT's. Because U.S. entities in effect control only half of the circuit in any international connection, U.S. policies on international telecommunications can be neither formulated nor implemented in a vacuum.

---

[61] See: "Intelsat, Policymaker's Dilemma." Judith Tegger Kildow (Lexington, Mass: Lexington Books, 1973); Global Communications satellite Policy, Joseph N. Pelton (Mt. Airy, Maryland: Lomond Books, 1974).

[62] Ibid.

[63] Ibid.

2. Recent policy developments

Rapid advancements in telecommunications and computer technologies have wrought significant economic and social changes. The merger of these technologies make possible a growing array of new information systems and services and blur traditional market boundaries. As industry structures change in response to the opportunities afforded by the new technologies, existing legal and regulatory frameworks often become outmoded. At the same time, the United States is facing a changing international environment in which competition from abroad is increasing and new barriers to free trade are emerging. As these developments occur, they give rise to a host of new policy questions and the need to reassess existing rules and procedures. Recent actions in Congress and the Federal Communications Commission [FCC] highlight the growing concern over the need to promote and protect U.S. information and telecommunications interests internationally and the lack of consensus on the best approach to accomplish this.

Several measures were introduced in the 97th Congress which are of particular relevance to international communications policymaking. Section 202 of Public Law 97-259 directs the National Telecommunications and Information Administration [NTIA] to conduct a comprehensive study of the long-range international telecommunications and information goals of the United States. This study is to focus on the policies and strategies necessary for accomplishing those goals and to review existing institutional structures and procedures for formulating policy in this area. Among the topics which this study is expected to address are such issues as how to increase competition in international telecommunications services and the U.S. posture in international organizations, including the International Telecommunications Union and Intelsat.

Another recent legislative initiative, the International Telecommunications Deregulatory Act of 1982 (S. 2469), was introduced by Senator Barry Goldwater on May 3, 1982. The legislation strives to promote competition among providers of international telecommunication services and to improve coordination of U.S. policymaking in international telecommunications. Senator Goldwater highlighted these dual concerns in his introductory remarks. He stated that:

> This bill makes clear that Commission [FCC] jurisdiction must encompass marketplace competition in the provision of international telecommunications services, and

that technological advances are making possible competition among providers of international telecommunications services.[64]

He further commented that:

> While many nations have taken steps to prepare and plan for and control these developments [technological advancements], the United States alone among the industrialized nations lacks a comprehensive, cohesive set of national goals and policies and the institutional structure to deal with these events.[65]

S. 2469 attempts to remedy these problems by establishing a U.S. policy which relies "wherever and whenever possible on marketplace competition and on the private sector to provide international telecommunications services * * *."[66] The bill also would amend the Communications Satellite Act of 1962, by allowing construction and operation of Earth stations by parties other than Comsat and by permitting Comsat to offer its services directly to end users. These issues will be discussed further in the section on promotion of competition. In addition, the bill creates an International Telecommunications and Information Task Force as the "principle coordinating body for the development of United States telecommunications and information policies."[67]

The Federal Communications Commission likewise recently moved to promote increased competition among U.S. suppliers of international telecommunications services. On August 5, 1982 the FCC announced a number of significant decisions and opened several new dockets which may have a significant impact on the international satellite system. Key among these are the removal or restrictions on Comsat as strictly a "carrier's carrier" and permitting Comsat to offer services directly to end users in competition with other international common carriers. In perhaps the most controversial and least clear decision in terms of its long-range implications the Commission also affirmed its earlier determination that the Computer II decision [77 FCC 2d 384, 462 (1980)] which delineated between basic and enhanced services for purposes of regulation be applied internationally. Finally, the FCC initiated two inquiries which may have a significant impact on Intelsat. One raised the issue of whether entities other than Comsat should be allowed to have their own Earth stations and the other the question of whether other carriers should be allowed direct investment in the Intelsat space segment.

The different perspectives on the issues raised by these recent FCC and congressional actions will be discussed in more detail in the following sections. However, they illustrate that policies currently are under review which directly and indirectly affect U.S. posture on international telecommunications and this nation's relationship to the Intelsat system.

At issue are such questions as what should the U.S. strategy in international telecommunications be? How can U.S. interests best be protected internationally? How can differing foreign policy and economic concerns be reconciled? How can the U.S. position favoring competition be successfully promoted internationally? What is the impact of the U.S. deregulatory trend on our international obligations and relationship with Intelsat? Who should be defining international policy—Congress, the executive branch, or the Federal Communications Commission? What should be the key components of that policy? How can the interests of various parties involved in international telecommunications be dealt with equitably? Who should be responsible for implementing international telecommunications policy? Is the current government structure adequate to both determine policy and to implement it or is some new organizational scheme necessary? The following discussion of some of the specific problems and issues facing U.S. policymakers may provide a framework for viewing the future of Intelsat and the international telecommunications system.

---

[64] Congressional Record. May 3, 1982. p. S4434.

[65] Ibid.

[66] 97th Congress, 2d session. S. 2469. p. 11.

[67] 97th Congress, 2d session. S. 2469. pp. 52–53.

3. Promotion of competition

Recent Federal Communications Commission actions and congressional initiatives are designed to promote competition as a major goal of U.S. international telecommunications policy. The best methods for achieving that goal, however, have yet to be determined. The FCC's determination on August 5, 1982 to extend its earlier Computer II decision internationally has, in particular, raised a host of questions about what approach should be taken to foster U.S. policies in the international environment.[68]

Authorities in the field do not agree on the precise interpretation and effect of this decision, but several industry groups have petitioned for reconsideration of the order. They assert that it will actually diminish competition and adversely affect U.S. telecommunications service providers and users because of a backlash from European countries which prefer not to deal with numerous companies.[69] In addition, they point to the negative reaction received from the Director of the International Telecommunication Union's Consultative Committee on Telephone and Telegraph [CCITT] who expressed concern that the decision might result in potential violations of existing international telecommunications regulations.

Opponents of this decision state that the adverse consequences are already materializing and that the full significance of extending domestic policies on deregulation into the international environment needs to be ascertained before proceeding further. Specifically, those opposing extension of Computer II internationally point to inconsistencies between this decision and other FCC determinations, negative reaction from foreign governments and international organizations, inadequate analysis of the ultimate impact of the decision, and the prejudicing of ongoing proceedings on international resale and shared use policies as reasons for the FCC to reconsider its decision. In addition, these industry groups cite examples of how foreign companies and governments will use this decision to bypass the authority of the FCC and establish what may be exclusive arrangements for international telecommunications services to the detriment of U.S. enterprises and users.[70]

---

[68] FCC 82-377 (released Aug. 25, 1982).

[69] See: Petition for Reconsideration of Association of Data Processing Service Organizations [ADAPSO] and Petition for Reconsideration of the International Communications Association [ICA], Sept. 24, 1982, re: GTE Telenet Communications Corp., file No. I-T-C-81-274 and Tymnet, Inc., file No. I-T-C-81-210.

[70] Ibid.

Defenders of the FCC's decision to extend Computer II internationally view it strictly as a means of removing common carrier regulation from enhanced service providers and hence increasing competition. They contend that it is not a broader policy shift away from existing U.S. obligations under current agreements with foreign telecommunications authorities or international organizations. They further suggest that this narrowly defined decision does not prejudice other pending proceedings and that by improving communications with foreign entities adverse reaction can be avoided.[71]

Whatever the outcome of this controversy, it raises substantial questions concerning how the United States can pursue policies of increasing competition in international telecommunications. Can there ever be true competition internationally when foreign governments are determined to foster their own national goals? Even if the international marketplace is not openly competitive, can the U.S. segment be so? How do we insure that U.S. competitive policies are not used ultimately against U.S. enterprises attempting to operate internationally?

If greater competition is to be achieved, what type of transition might be necessary? Should competition be limited to service providers or should competition in international telecommunications facilities also be promoted? What changes in U.S. regulatory structure and legal authority might be needed to promote competition? Who will determine the winners and losers in this changing environment? How will users of these international telecommunications services, including small businesses and the American consumer be protected? What will be the impact on Intelsat—organizationally, technologically, and for its users—should the United States continue to promote increased competition in international telecommunications services?

a. Competing satellite systems.—Competing domestic, regional, and transborder satellite systems are viewed by many as a major threat to the Intelsat global system. It is sometimes difficult for Intelsat to predict and accommodate customer demand. The result is the establishment of specialized regional and domestic satellite systems, such as Arabsat, Palapat-B and the European Communications System, which have the potential for creating market competition with Intelsat. In an effort to diminish the potential for competing satellite systems the definitive agreements [Article XIV] require signatories to consult with Intelsat before utilizing or developing satellite systems which might cause technical interference or significant economic harm to Intelsat.

While all of these systems have been coordinated with Intelsat under the Article XIV procedure, their continued proliferation raises questions about the future for a single global satellite system. This conflict was highlighted recently when Intelsat agreed to coordinate with the expanded European satellite system Eutelsat, only for a period of five years. Intelsat expects that it will be able to satisfy the need for Eutelsat's services after that time. The European nations reacted strongly to this decision, asserting that it could cause significant economic harm to the system. In addition, the decision raised long standing European animosity about the dominant role that Comsat plays in Intelsat and the controlling share of the international communications market enjoyed by American firms.[72]

---

[71] See: Opposition of International Business Machines Corp. [IBM] to petitions for reconsideration, Oct. 26, 1982, in re: GTE Telenet Communications Corp., file No. I-T-C-81-274 and Tymnet, Inc., file No. I-T-C-81-210.

Of equal concern for the future of Intelsat may be the increasing demand for transborder satellite services. Recently, the Federal Communications Commission approved thirteen transborder service applications.[73] Although most of these applications were for services between the United States and Canada which have not used Intelsat facilities, others were for points in the Caribbean and Central America which have been served traditionally by international facilities.

The Department of State has lent its support under certain circumstances to the use of domestic satellites for transborder services. In a letter to FCC Chairman Mark Fowler, James Buckley, Undersecretary of State for Security Assistance, Science and Technology, reiterated U.S. support for Intelsat and a global satellite system. He also noted the need to in some instances rely upon facilities separate from Intelsat. He stated that such applications should be approved if they meet either one of two criteria: (1) the global system could not provide the service required; or (2) the service planned would be clearly uneconomical or impractical using Intelsat.[74] While the United States maintains its traditional commitment to the global Intelsat system, it may be under increasing pressure to reconcile this commitment with the growing desire to use U.S. domestic satellites for transborder services.

The movement toward increased transborder and regional satellite activities is a reflection of the desire for better economic efficiency and improved specialized services. Although Intelsat has taken some recent steps toward improving facilities and adding new services, there remains some question of its ability to provide sufficient service, innovation, and flexibility to satisfy user needs on a cost-effective basis. The fact that the new British Unisat satellites will have transatlantic capabilities and future French domestic satellites will be able to handle regional and transatlantic services likewise may provide additional pressures on the existing Intelsat global system. Other pressure also may result if the predictions by some industry observers of a transponder glut materializes and excess capacity on domestic satellites appears attractive for international traffic. Will Intelsat be able to accommodate its users adequately as technological options and economic pressures increase so that a proliferation of competing satellite systems can be avoided? Will Intelsat have to revise its pricing policies if such competition increases? How can the United States insure that its foreign policy objectives for a global satellite system don't conflict with its efforts to promote economic efficiency?

---

[72] Satellite Week, "Europeans Furious at Americans as Intelsat Rift Widens," vol. 4, No. 39, Oct. 4, 1982, pp. 4-5. Satellite Week, "Eutelsat News Release Aims Squarely at Intelsat", vol. 4, No. 41, Oct. 18, 1982, pp. 1-2.

[73] Transborder Satellite Video Services, FCC 81-492 (released Oct. 30, 1981).

[74] Letter to Hon. Mark Fowler, Chairman, Federal Communications Commission from James L. Buckley, Under Secretary of State for Security Assistance, Science and Technology, July 23, 1981.

b. Intermodal competition.—Until recently, U.S. regulatory policy for international telecommunications essentially eliminated competition between satellite and cable operations. The FCC's "proportional fill" rule was designed to achieve 100 percent utilization of cable and satellite facilities by allocating international traffic between the two.[75]

However, the FCC decision allowing Comsat to serve end users directly also made discretionary its policy under which international rates are set by averaging cable and satellite transmission costs. It further raised the issue of the role of the FCC in allocating the load between satellite and cable facilities, and whether in the future this might be determined by marketplace competition.[76] Some industry analysts question, however, whether true intermodal competition is possible without other changes to the differing cable and satellite tax and rate base structures. For example, cable investment enters into the rate base of the International Record Carriers, while satellite leases must be expensed.

Another factor in competition between satellites and cables in the long-range is the potential of new technologies to provide alternative modes of transmission. Fiber optic cables, for example, promise to provide increased efficiency and lower costs for data transmission. As information—voice, record, and video—is transmitted increasingly in digital form, fiber optics offer the potential for delivering a wide variety of services. On the other hand, although fiber optics may provide greater competiton for satellites, significant amounts of fiber optic cable may not be installed for another decade. In addition, requirements for broadband communications and facilities which are insensitive to distance will continue to make satellites important. Another potential development is the ability to link domestic satellites in the United States with those in Europe via inter-satellite beam. Can the concept of intermodal competition truly be applied in a situation where each type of facility offers unique features and advantages? Will further changes to rate base structures be needed to achieve competition? Will technological developments undermine Intelsat's current advantages in international telecommunications? If so, how will Intelsat respond to these future technological developments and their impact on international telecommunications?

c. Direct access to Intelsat space segment.—It has been argued tht if Comsat is allowed to provide services directly to end users as the FCC's August 5, 1982 decision allows[77] the international service carriers should be permitted direct access to Intelsat's space segment. The International Record Carriers [IRC's] maintain that they are placed at a disadvantage in the marketplace because of Comsat's monopoly position with Intelsat. They assert that competition cannot be achieved unless the IRC's can "obtain economic, operational and informational access to the international satellite system on terms equivalent to those Comsat receives," what the

---

[75] Federal Communications Commission, in the matter of American Telephone and Telegraph Co., ITT World Communications, Inc., RCA Communications, Inc., Western Union International, Inc. Memorandum opinion, order, and authorization, 13 FCC 2d 235 (1968).

[76] FCC 82-357.

[77] Ibid.

IRC's term "cost/based" access. Cost-based access is viewed as one method for establishing appropriate incentives for competition.[78]

Several options have been offered for achieving cost-based access including allowing "carriers to purchase satellite circuits directly from Comsat, on an indefeasible right-of-user [IRU] basis." [79] Under this arrangement the holder of an IRU would have in effect ownership rights to a portion of the communications facility, but would not be able to participate in management decisions affecting the facility as a whole.[80] Another option could be a long-term capital lease. Under these arrangements Comsat would receive a fee to cover the cost of coordination, management, and maintenance activities. In addition, it has been suggested that Comsat be required to offer Intelsat space segment and Earth segment facilities under separate tariffs.

The Federal Communications Commission issued a Notice of Inquiry on August 6, 1982 into the question of direct access to Intelsat space segment by U.S. international service carriers.[81] The FCC specifically requested comments on whether a policy of direct access might be desirable and if so, what approaches to access might be most beneficial.

Commissioner Abbott Washburn voiced several reservations to allowing direct access to Intelsat which reflect another side to the issue. He noted that: [82]

> In my view, there is a serious legal question as to whether the Communications Satellite Act of 1962 and the Intelsat Definitive Arrangements negotiated in 1969-1971 can be construed to allow capital investment in the INTELSAT space segment by any but the legally designated U.S. entity, COMSAT, as Signatory. A proliferation of investing non-signatories was never envisioned.

Commissioner Washburn further questioned whether the potential benefits to be achieved by allowing direct access might be outweighed by the potential disruption to the Intelsat system—one which has served well the global community. Finally, he doubted that the suggested methods of investment necessarily would lead to reduced prices and improved services for the consumer.[83]

Should investment in Intelsat by other carriers be allowed since Comsat is now permitted to provide services to end users? Will this violate U.S. legal commitments to Intelsat or damage technologically or economically the global communications system? If direct access is allowed, what type of investment arrangements should be established? Should regulatory distinctions be maintained between the owners, operators, and users of satellite facilities?

d. Earth station ownership.—The FCC is responsible for determining what entities can be authorized to construct and operate U.S. Earth stations operating with Intelsat in accordance with the Communications Satellite Act of 1962. Comsat was given the initial authorization in 1965 to own and operate the first three U.S. Earth stations. Subsequently in 1966, the FCC revised its policy so that all Earth stations would be owned jointly by Comsat and other international carriers in what is called the Earth Station Ownership Committee [ESOC]. Under this arrangement Comsat owns 50 percent and the other carriers 50 percent with Comsat serving as manager of the stations.

---

[78] Testimony of Eugene F. Murphy, chairman of RCA Global Communications, Inc. before the Senate Committee on Commerce, Science, and Transportation, Subcommittee on Communications, June 15, 1982. App. A, p. 1.

[79] Ibid., app. A., p. 3.

[80] Ibid.

[81] Notice of inquiry, (FCC 82-374)

[82] Concurring statement of Commissioner Abbott Washburn. Common carrier item No. 4, Aug. 5, 1982. NOI on proposal to allow U.S. international service carriers "direct economic access to the Intelsat space segment.

[83] Ibid.

In light of the Commission's decision to allow Comsat to offer services directly to end users, the FCC also initiated a Notice of Inquiry into ownership and operation of U.S. Earth stations that operate within the Intelsat system.[84] This inquiry will look at the question of whether individual or group ownership of general purpose and/or special purpose U.S. Earth stations should be permitted outside the current ESOC arrangement.

On one side of this issue are the International Record Carriers who advocate Earth stations ownership independent of ESOC. On the other side is Comsat, which contends that a proliferation of Earth stations would be detrimental to the efficiency of the global communications system.

The International Telecommunications Deregulation Act of 1982, S. 2469, would amend the Communications Satellite Act of 1962 to allow construction and operation of Earth station to others than Comsat if it served the public interest. At hearings on the legislation U.S. Telephone and Telegraph Corporation [ITT] testified that:[85]

> If Comsat is to retain special monopoly privileges while also being allowed to expand into new competitive markets, the strictest possible preconditions must be imposed.

Included would be requirements to "abrogate the Comsat-dominated Earth station ownership consortia" and "allowing competing carriers to establish their own separate Earth stations or otherwise obtain Earth station capacity on the basis of need."[86] Advocates of alternative Earth station ownership arrangements contend that advances in technology make it possible for additional Earth stations to operate—at least in a receive-only mode—without significant disruption or alteration to the Intelsat space segment. At the same time, they contend, the ability to access Intelsat directly will increase efficiency and reduce the costs associated with using Comsat as an intermediary.

These views, however, are not universally shared. At the same hearings, Comsat testified that "Earth stations with direct access to Intelsat would result in costly inefficiencies and a degradation of service for all system users."[87] Dr. Joseph V. Charyk, President of Comsat stated that:[88]

---

[84] Notice of inquiry (FCC 82-373).

[85] Testimony of Howard A. White, executive vice president and general counsel, U.S. Telephone and Telegraph Corp. [ITT] before the Senate Committee on Commerce, Science, and Transportation, June 15, 1982. p. 8.

[86] Ibid.

[87] Statement of Dr. Joseph V. Charyk, president and chief executive officer, Communications Satellite Corp. on S. 2469 before the Senate Committee on Commerce, Science, and Transportation, Subcommittee on Communications, June 15, 1982. p. 7.

[88] Ibid.

> The system therefore depends on extensive frequency reuse techniques with limited coverage down-link beams for the space segment and large, highly sensitive earth station antennas with high polarization isolation and narrowly shaped beams for the ground segment.

He concluded that "to maintain an acceptable level of efficiency, the Intelsat space segment as designed cannot accommodate a multiplicity of small, relatively inexpensive, Earth stations."[89]

Related to the issue of Earth stations is the potential development of large geostationary [GEO] platforms. Currently under study by NASA, GEO platforms dedicated to communications would maximize efficient use of the geostationary arc and satellite power. Would the introduction of GEO communications platforms permit multiple access from small antennas in a cost-effective and technically efficient way? Would such technological development eliminate the need for some of the centralized access functions performed by Comsat?

The FCC's inquiry will address such questions as: What is the effect of independently owned Earth stations on Intelsat's planning and coordination process? What would be the administrative and operational ramifications of multiple Earth stations accessing Intelsat? How cost-effective would new ownership policies be? Who might benefit and who might lose if new Earth station policies were adopted?

4. International resale of telecommunications circuits

The Federal Communications Commission attempted to deregulate resale and shared use of international communications circuits in 1976, at the time it issued its Report and Order concerning domestic resale and shared use. On reconsideration, after objections were raised by numerous parties to the application of these domestic policies internationally, the Commission decided that international resale and shared use should be treated separately at a later time.

Subsequently, in May 1980, the Commission issued a Notice of Proposed Rulemaking [NPRM] on international resale and shared use. In releasing this NPRM, the Commission stated that its goal was to eliminate price discrimination among comparable services, increase the number of firms and services among which telecommunications users might choose, stimulate the development of new services and marketing techniques, and encourage innovation in the uses of basic services.[90]

The response to this NPRM was overwhelmingly negative by both U.S. international service carriers and foreign telecommunications administrations. Perhaps the most notable reaction came from the director of the International Consultative Telegraph and Telephone Committee [CCITT] of the International Telecommunications Union which is responsible for setting international standards and proposing regulations for interconnection. In a letter to the Department of State, Mr. Burtz stated that Recommendation D.1 of the CCITT specifically forbids the resale and shared use of international circuits—a regulation which the United States played a role in formulating.[91] Mr. Burtz questioned:

---

[89] Ibid., p. 8.

[90] CC docket No. 80-176.

> What credibility can the United States delegation to future CCITT meetings, and more generally in the ITU, expect to have, if your administration decides to apply to international private leased circuits provisions conflicting with those which it has approved at the international level within the framework of the CCITT.[92]

As a result of the adverse reaction both in the United States and abroad, the Commission has not proceeded further on this issue.

Recently, the resale issue has emerged again in both Congress and the FCC. In testimony before the Senate Subcommittee on Communications, numerous witnesses opposed the proposed resale section of S. 2469, the International Telecommunications Deregulatory Act. Citing the negative response received 2 years earlier to the Commission's NPRM, both Government and private sector witnesses warned against unilaterally extending our domestic resale policy to the international marketplace. International service carriers indicated that foreign PTT's threatened "to 'cancel' international circuits used for resale purposes" should the United States adopt such policies and that this "might result in increased international communications costs of several billion dollars annually."[93] The legislation was subsequently amended by the Committee on Commerce, Science, and Transportation which removed the resale provision from the bill and replaced it with a statement of policy "to promote, including through meetings with foreign telecommunications entities, the deregulation of the resale or shared use of any international telecommunications service."[94]

Another recent action, discussed earlier, which is highlighting the issue of international resale of telecommunications circuits in the FCC's determination that the Computer II decision applies internationally. Although FCC staff asserted that this results soley in distinguishing between basic and enhanced services internationally, others contend that the ultimate effect is an international resale policy.[95] As noted in the previous discussion of this decision, although considerable argument exists concerning the implications of extending Computer II internationally, adverse reaction from European telecommunications authorities and the International Telecommunications Union have already surfaced.[96]

Is it possible for the United States to pursue such domestic policies as resale of telecommunications circuits internationally? Will the desired increase in competition be possible without causing foreign telecommunications authorities to take retaliatory actions which would serve to increase costs and reduce access to markets? Can any of these policy objectives be accomplished without concurrence by overseas PTT's and international organizations such as the International Telecommunications Union and Intelsat? How can the United States insure that policies it pursues in various fora are consistent?

---

[91] Letter from L. Burtz, director of the CCITT of the International Telecommunications Union to Mr. Arthur Freeman, Director, Office of International Communications Policy, Department of State, June 20, 1980.

[92] Ibid., p. 3.

[93] Testimony of Robert E. Conn, Western Union International, Inc. before the Senate Committee on Commerce, Science, and Transportation, Subcommittee on Communications, June 15, 1982, p. 21.

[94] S. 2469, 97th Congress, 2d session. (Also see Filings.)

[95] Satellite Week, vol. 4, No. 31, Aug. 9. 1982, p. 2-3.

[96] Communications Daily, Oct. 22, 1982. p. 2.

5. *Foreign policy considerations*

Technical expediency and economic efficiency were major U.S. goals in establishing Intelsat. However, at the same time, the United States has pursued a foreign aid strategy through the implementation of communications satellite technology. The United States has supported, and indeed fostered, a goal of subsidizing services for the less developed countries (LDC's). Both the Communications Satellite Act of 1962 and the Intelsat agreements are designed to foster equity of access to the global satellite system and the United States has consistently supported such a concept.

Should the United States adopt a policy which promotes greater competition and presses for reduced costs, there may be adverse economic consequences for other members of the Intelsat system—particularly, the less developed countries. If it is determined that the United States should continue its policy of subsidizing telecommunications services for the LDC's and support Intelsat's current pricing arrangement, then who should pay that price? Should it be borne by the U.S. Government, by U.S. businesses, and/or the American consumer? In addition, what other avenues might the United States pursue to help developing countries establish adequate telecommunications facilities and services and assure fair access to the global satellite system? How can Intelsat respond to pressures for reduced prices and increased services in more competitive regions, while still maintaining adequate service at reasonable costs for smaller users?

F. CONCLUSION

By virtually all measures, Intelsat has been a major success. Today the dream of a global statellite serving the nations of the world has been realized. The United States played a critical role in establishing the Intelsat system. It continues to support its operations both through its advocacy for Intelsat as a worldwide satellite system and through the key position of Comsat as Intelsat's technical manager and major shareholder.

The international setting today, however, is significantly different from what is was when Intelsat was created almost 20 years ago. Intelsat faces the challenge of maintaining a viable international satellite system which can provide needed services at reasonable rates. As regional systems grow, user demands for specialized business services at decreasing costs become greater, and technological development offer new alternatives, Intelsat may have to reassess some of its current policies and procedures. At the same time, the United States is confronted with the need to reevaluate its policies toward international telecommunications. In particular, the desire to promote competition in international telecommunications services, to increase the availability of services, and to reduce costs may have to be reconciled with traditional foreign policy concerns and the longstanding commitment to support a global satellite system. To what extent Intelsat's existing monopoly should be protected, may be expected to receive increased attention both in the United States and abroad in the next several years.

IV. AERONAUTICAL COMMUNICATIONS SATELLITE (AEROSAT)

A. Introduction

The increasing congestion and predicted saturation of the High Frequency (HF) band for aeronautical communications prompted the airlines and various Government agencies, in the 1960's and early 1970's, to examine transoceanic communications systems. Consensus centered on a communications satellite as an effective solution to the aeronautical communications problem. In order to avoid a fragmentary approach and competing technical designs, European cooperation was sought in the development of an aeronautical communications system. After lengthy negotiations, a joint Memorandum of Understanding was signed in 1974 for initiation of a joint United States-European-Canadian program to develop an aeronautical communications satellite system for an improved transoceanic communications link between aircraft and air traffic control centers.

Beginning in 1974, the Aerosat program experienced technical delays, rising costs, increasing dissatisfaction from the user community, contract disputes, and congressional disenchantment. Finally, in the spring of 1977, all funds for Aerosat R&D were deleted from the Federal Aviation Administration fiscal year 1978 budget with orders that the program be reevaluated and less expensive alternative communications systems be considered.

The history and evolution of the Aerosat program raise important policy issues which must be resolved in order to circumvent similar problems in future attempts to implement space applications technology. In order to understand the policy issues involved in the Aerosat controversy, it is first necessary to review the long and often torturous history of the program.

B. History

1. *Early history*

Recognizing the limitations of the high frequency radio communications band and predicting a large increase in transoceanic air traffic, the Air Transport Association (ATA) and several U.S. international air carriers advocated the development of an aeronautical communications satellite capability. In 1964, the ATA asked the Communications Satellite Corporation (Comsat) informally for an assessment of the feasibility of VHF communications with aircraft via satellite.[97] Comsat made several studies and discussed require-

---

[97] Radio frequency band designations:

Internationally accepted system

Band 1—VLF (very low frequency)	3 to 30 KHz.
Band 2—LF (low frequency)	30 to 300 KHz.
Band 3—MF (medium frequency)	300 to 3,000 KHz.
Band 4—HF (high frequency)	3 to 30 MHz.
Band 5—VHF (very high frequency)	30 to 300 MHz.
Band 6—UHF (ultrahigh frequency)	300 to 3,000 MHz.
Band 7—SHF (superhigh frequency)	3 to 30 GHz.
Band 8—EHF (extremely high frequency)	30 to 3,000 GHz.

•For the purposes of this chapter, UHF is used synonomously with L-Band.

ments and feasibility with Arinc,[98] the airlines, and the Federal Administration (FAA). Comsat then issued a preliminary report which indicated the feasibility of a voice channel capability with near-term technology.

Interest in an aeronautical communications satellite was heightened with the first pioneering feasibility demonstration of air-to-ground communications by a Pan American Airlines jet using the Syncom 3 satellite (January 1965). Comsat issued a request for proposals. In its filing, Comsat said:

> A limited initial service capability is planned for the Atlantic region primarily aimed at alleviating the communications gap along the high density North Atlantic routes by supplementing the present unreliable HF (high frequency) aeronautical service.
>
> Secondarily, it is aimed at providing the necessary technical and operational experience to permit an orderly expansion of the satellite aeronautical services on a global basis.[99]

In 1966, Comsat announced its plans to develop an aeronautical communications satellite—called Aerocom—to be located over the Equator between Africa and South America by as early as 1968. The satellite was to relay aircraft transmissions to two ground stations—one in North America and the other in Europe. The VHF frequency was chosen to avoid the necessity of replacing airborne VHF equipment with UHF equipment. It was also thought that VHF antenna technology exceeded the state of the art of UHF technology, and that a technical development period of 5 to 10 years would be required to design a UHF antenna that would be compatible with the system. [It is important to note that although the decision was made in favor of VHF, there was general agreement that a research and development program was needed to determine the potential of the UHF band for future use.] If UHF technology was perfected, UHF equipment would gradually phase out VHF equipment.

The airlines greeted this news with enthusiasm. According to W. W. "Buck" Buchanan, director of systems planning for Arinc, no development in airline operational communications since the radiotelephone "has offered so much promise or generated as much enthusiasm and support from the airlines." [1]

Domestic developments were accompanied by international interest. In 1966 the International Civil Aviation Organization (ICAO) considered the question of space communications as a separate agenda item. There was much debate on technical, operational, and financial aspects of the prospective new services. Among those points which were agreed upon were the need for an aeronautical communications system by the end of the 1970's and, of particular significance, the recognition of a need for extensive operational evaluation programs prior to determination of the desirable characteristics of a fully operational system. This desire to have a preoperational system prior to a permanent network was to prove important in later negotiations.

---

[98] Aeronautical Radio, Inc. (ARINC)—provides radio communication for air carriers.

[99] Comsat News, April 1966.

[1] Henkel, Robert. "Satellite in Sight for Airlines." Electronics, October 1966, p. 5.

2. Comsat proposal

Between 1967 and 1969, Comsat conferred with the FAA and Arinc to develop a satellite service whose costs would be acceptable to the users. Several proposals were submitted to the FAA and Arinc and rejected due to high cost of the service. When Comsat proposed a system which was acceptably economical to the FAA and Arinc, an operational plan based on a Pacific satellite was drafted.

Under the Comsat proposals, the FAA and the airlines would each lease one channel on an exclusive basis and share a third. The fourth VHF channel would be available for rental to other international carriers and for aviation agencies operating in the Pacific. No capital investment would have been required of any of the users. The proposed Pacific trial evaluation was termed "preoperational" because it was expected to provide useful operational capability. In addition, a preoperational terminology would have enabled the FAA to charge its rental fees against its large projected operational funding rather than against a much smaller R&D budget and would justify airline investment in the required avionics.[2]

This proposal for a VHF satellite located over the Pacific clearly emphasized an expedient implementation of the technology and a postponement of a European interface. L-band technology was not yet fully developed, and if the United States and Europe were to develop jointly an L-band technology, political arrangements would require formal discussions between the U.S. Department of State and the Western European governments. VHF supporters argued that these discussions in addition to the difficult task of parceling out design assignment, to each of the many countries included, would likely delay L-band implementation, hence, the choice of a VHF technology in the Pacific arena.

3. ICAO opposition to Comsat plan

When the Aerosat proposal was then presented to ICAO's Application of Space Techniques Relating to Aviation (Astra) panel in the fall of 1969, it was opposed by the Western Europeans on several grounds. A technical issue involved the choice of frequency to be used in the satellite: VHF or UHF. All parties seemed to agree that UHF would be used ultimately since it could provide greater accuracy for such functions as air surveillance and navigation and is a less crowded area of the electromagnetic spectrum. It was also general accepted that VHF could be deployed sooner because the necessary equipment and technology were then available.[3]

However, European opponents of VHF feared that airline efforts to deploy a preoperational VHF satellite over the Pacific would unjustly influence the decision on what type of system would be chosen for the operational satellite.[4]

---

[2] Klass, Philip J. "Discord over Aero-Sat Increasing." Aviation Week and Space Technology, May 18, 1970, pp. 51-56.

[3] Ibid.

Further, the report issued by the Astra-2 Panel subsequent to its Montreal meeting cautioned against any attempt to proceed with a VHF satellite in the hope of trying later to ease it into a fully operational status. According to the Astra-2 report, "any preoperational system that does not include parallel (side by side) VHF and UHF experiments should not in itself warrant further expansion to an operational system in either frequency band.".[5]

4. Modified Comsat proposal to comply with ICAO recommendations

At the urging of the FAA Administrator, who felt that the United States should cooperative with the Europeans and comply with the wishes of the ICAO Astra Panel (for experimentation on L-band to match VHF experimentation), Arinc and Comsat changed the VHF satellite to a hybrid satellite. The proposed hybrid Aerosat was based on the development of a new Thorad-Delta launch vehicle with an increased synchronous orbit payload capability allowing the addition of an L-band transponder to Aerosat in order to provide the dual-band channels that had been specified by the Astra-2 panel. According to Comsat, the inclusion of UHF channels on the same spacecraft would permit the FAA and the National Aeronautics and Space Administration to conduct extensive tests and experiments in an operational environment at an early time without awaiting further Government research and development work on satellites or satellite equipment.

Comsat was prepared to finance, build and operate the system, and provide the services on a fixed charge basis. No user payments would be made to Comsat until the services were available.

The plan provided options for two-ocean or one-ocean (Pacific only) services. With the two-ocean approach, two satellites would be positioned in synchronous orbits initially over the Pacific. The second satellite would be moved to the Atlantic after completion of certain experiments expected to take approximately one year. These would include communications and propagation tests and ranging tests as well as other experiments to determine the best characteristics for a follow-on generation of aeronautical satellite services. The one-ocean system would consist of a single satellite over the Pacific alone.[6]

The ATA was enthusiastic about the proposal and endorsed it with one proviso:

---

[4] Langereux, Pierre. "Comsat and Arinc Urge the U.S. Airlines to Finance Their Aeronautical Satellite Project." Air and Cosmos, Sept. 27, 1969, translation. Aside from technical considerations, one reason the Europeans may have so strongly advocated an L-band North Atlantic system is that if the United States were to proceed with a VHF Aerosat, the entire system development would probably be performed by American companies. In addition, U.S. avionics companies, three of which already offered the high-power amplified and low-noise VHF transceivers needed for satellite operation, would dominate the aircraft avionics market. The European, who had developed some expertise in L-band technology, would have been more competitive in the development of an L-band satellite.

[5] Klass, Philip J. "Discord over Aero-Sat Increasing." Aviation Week and Space Technology, May 18, 1970, p. 32

[6] Summary: Aeronautical satellite services proposed by Comsat. Comsat press release No. 70-28, May 12, 1970.

> If at any time it becomes apparent that the hybrid proposal will be unsuccessful for political, financial, technical, or any other reasons, the airlines would like assurance from the FAA that we would jointly revert to the VHF-only proposal.[7]

In addition, the ATA endorsed the hybrid concept on behalf of the airlines providing ESRO and NASA would underwrite half of the cost of the satellite, with the other half being funded by FAA and the airlines.

5. ICAO rejection of Comsat proposal

When the Astra-3 panel convened in Paris (1970) the Western European representatives rejected the hybrid proposal. They presented voluminous data to show that VHF was more vulnerable to periodic atmospheric conditions that its proponents realized. Additional data were offered to show that UFH was superior for communications as well as for air traffic surveillance. In addition, the fact that in the proposal the VHF portion was termed for "preoperational" tests while the L-band was referred to as "experimental," tended, according to the Astra-3 panel, to favor VHF.[8]

Further, more aircraft were likely to be equipped with existing VHF equipment than with experimental L-band hardware. The Astra–3 panel decided that this situation would make it "difficult subsequently, in some circumstances," that is, the Astra panel feared the entrenchment of a VHF system, by virtue of a sizable airline investment in airborne equipment.[9]

6. NASA/ESRO proposal for L-band Atlantic system

Concurrent with the FAA/airline impasse in negotiations with the Europeans were efforts by NASA to establish a joint NASA/ESRO aeronautical communications satellite program. NASA officials met with ESRO representatives and eventually reached general agreement on the specifications for an L-band aeronautical communications satellite system for the North Atlantic. It was to provide both air-to-ground communications and aircraft surveillance in the North Atlantic beginning in 1974–1975.

7. Airline opposition

The International Air Transportation Association (IATA) and the Air Transportation Association (ATA) issued a joint statement opposing the NASA/ESRO plans for a North Atlantic L-band satellite system. The airlines viewed the relative superiority of UHF for aircraft surveillance as superfluous because they claimed that there was no stated operational requirement for aircraft surveillance over ocean routes. The joint IATA/ATA statement complained that the proposed system was "not responsive to valid internationally agreed operational requirements, but reflects the intent to apply satellite technology regardless of the need or costs." It further criticized the NASA/ESRO efforts for "lack of adequate consultation with the airlines." According to the statement, the airline industry disassociated itself from "future financial participation either through user charges or through the carriage of airborne equipment at airline expense.[10]

---

[7] ATA letter to FAA, Feb. 2, 1970.

[8] However, from FAA's viewpoint, to call both experimental would have made it impossible to pay rental charges out of the agency's much larger operational budget.

[9] Klass, Philip J. "Discord over Aero-Sat Increasing." Aviation Week and Space Technology, May 18, 1980, pp. 1–8.

The airline industry also reacted negatively to assigning NASA the lead role in the technological development of an aeronautical satellite. The airline spokesman seemed to feel that the FAA was in a better position to be aware of user needs:

> FAA may be the only agency that is fully aware of the broad issues, and the consequences, of any decision that might be made today in the U.S. Government. . . . Long experience, sometimes bitter, has shown FAA that system implementation is futile when such desires and needs are not satisfied. Therefore they would be doubly cautious in appending their approval to a satellite system known to be objectionable to the airlines. FAA is further well aware of the necessity for accommodating, as far as practicable, the desire and needs of international bodies and other countries.[11]

The airlines feared that technological development would take precedence over user needs:

> The NASA/ESRO combine seems competely unaware of any of the ramifications of the frequency-band issue. The August 12 meeting confirmed the suspicions of the airline people . . . that FAA's NASA advisors and the whole of ESRO organization have been so deeply involved in space research that they have had a shallow comprehension of the "real live world of civil aviation."[12]

8. FAA proposal—hybrid system

The FAA continued to support a hybrid satellite program. In a speech at the 18th Annual Technical Conference of the International Air Transport Association, the FAA's position was clearly summarized:

> FAA recognizes the respective merit of both VHF and UHF in meeting the air/ground communications requirement as well as other stated requirements such as standards of reduced separation, provision for digital communications and eventual capability for surveillance. But we believe it is too early for a final decision on the essential characteristics of the world wide operational aeronautical system and that further research in both VHF and L-band is necessary before a rational and responsible choice can be made.
>
> The agency's position, therefore, is very similar to the one taken by the domestic and international airlines. We support a hybrid aeronautical satellite system incorporating both VHF and UHF capabilities as the logical evolutionary step leading to the development of a global system for operational use. The hybrid system would provide VHF for early operational use and UHF for experimentation and comparative evaluation. This, in turn, would create a solid basis for reaching a sound decision as to choice of frequency for an ultimate system. However, because of the controversy which surrounds that subject of satellite communications among the states of the North Atlantic, the agency proposes that this first generation system be deployed to provide service in the North Pacific, an area where FAA has the primary responsibility for air traffic control. Moreover, to achieve an early launch of this system, the agency supports an arrangement whereby the Government and the user airlines would lease satellite communications capability. Such an arrangement would be in consonance with the Government's policy of utilizing commercial communication facilities whenever possible and minimize the impact on the Federal budget. By going this route, we estimate that a hybrid satellite system could be available during 1973.[13]

Shortly after the FAA reaffirmed its proposal for a hybrid satellite, John S. Anderson, chairman of the board of Aeronautical

---

[10] Klass, Philip J. "Controversy Grows on Frequency for Use on Aeronautical Satellite." Aviation Week and Space Technology, June 29, 1970, p. 34.

[11] Where is the ARINC Satellite?" Aero Line, Aug. 13, 1970, p. 3.

[12] Ibid.

[13] Remarks prepared for delivery by John H. Shaffer, Administrator, Federal Aviation Administration, at the International Air Transport Associations 18th technical conference, Miami Beach, Fla., Sept. 14, 1970, Department of Transportation News, p. 7.

Radio, Inc., endorsed the proposed system: "despite all the disruptive forces of the past year, nothing has altered the fact that the only satellite and avionics system that is essentially ready for implementation today to serve the decade of the 1970's . . . is the VHF satellite."[14]

9. Nixon administration policy—unilateral L-band Pacific satellite

In January 1971, the Nixon Administration released a "Statement of Government Policy on Satellite Telecommunications for International Civil Aviation Operations." The statement recommended that the United States proceed with a Pacific UHF aeronautical communications satellite on a unilateral basis. A unilateral program was chosen in order to expedite the implementation of the system. Other nations were, however, invited to participate.

UHF was chosen because it was considered to be technologically superior to VHF and it could provide more accurate position-fixing capabilities for aircraft surveillance. Also, the VHF bands were congested, particularly in Europe.

In a move which seemed to predetermine the existence of a future operational system, the White House ended the jurisdictional dispute between NASA and the FAA and designated the FAA "as the Federal agency with statutory operational obligations . . . to be the lead management agency and to assume responsibility for defining requirements, program budgeting, and management of preoperational and operational systems." NASA, which had earlier sought to assume responsibility for Aerosat development, would have a secondary role to "conduct independent research and development . . . and to provide other technical support unique to transportation applications."[15]

Finally, concurrent with the Administration's policy to encourage the private sector to develop and provide communications services, it was decided that Aerosat would be owned and managed by commercial ventures, with FAA leasing channels.

The response of both the European space community and the international airlines to the White House decision to deploy a unilateral preoperational system was overwhelmingly negative.

a. Negative airline reaction.—The airlines who had requested the less expensive VHF communications function-only satellite, were outraged at what they considered premature plans for an unnecessarily complex, and therefore expensive, satellite system. The airlines feared that they would be charged exorbitantly high user fees in order to pay for the system, which would necessarily have to be translated into increased passenger fares.[16]

---

[14] "ARINC Urges Deployment of VHF Aeronautical Satellite," Space Daily, Oct. 22, 1970, p. 23.

[15] Statement of Government policy on Satellite Telecommunications for International Civil Aviation Operations. Office of Telecommunications Policy, Jan. 7, 1971, mimeo p. 3.

[16] A Problem of Control, Flight International, Apr. 6, 1972, pp. 474–475. Article 15 of the 1944 Chicago Convention on International Civil Aviation, ratified by the United States in 1946 (61 Stat. 1180) established the authority for national administrations to levy user charges on operations of international air carriers. User charges are comprised of four general categories: landing charges, en route charges, fuel taxes, and passenger taxes. Included within these categories are the costs of communications services provided to international air carriers by various national administrations. The trend of user charges has risen drastically. User charges imposed on U.S. international air carriers increased from a total of $82 million in 1969 to a total of $124

Continued

b. European reaction.—The Western European space community was disappointed with the unilateral approach and urged cooperation in the development of the satellite, or at least technical coordination in designing the two systems. ESRO authorized the initiation of Phase I studies of a European communications satellite program. However, ESRO stated that it would be prepared to reorient or even discontinue the study if wider international collaboration could be arranged. [17]

10. FAA/ESRO proposal

Because of a universal dissatisfaction with the unilateral program, efforts were made by the members of the European Space Conference (ESC) [18] and the FAA to explore the possibilities for a unified preoperational program. After extensive exchange of views, it was decided that a unified program was desirable. An agreement was reached on the ministerial level on a two-ocean Aerosat system expected to cost approximately $120–150 million. Australia, Japan, and Canada were each to contribute $4 million toward development costs, and the United States and ESRO were to divide the remaining costs. Europoean aerospace and avionics companies were expected to share in approximately half the production of the four flight model satellites, and all launch vehicles would be built in the United States. [19]

The FAA decided that the Office of Telecommunications Policy (OTP) requirement for commercial ownership created a variety of complications. [20] The agency therefore decided that the preoperational system should be owned jointly by FAA and ESRO without prejudice to a future possible commercial arrangement for the next generation operational system [21]

The FAA/ESRO proposal met with serious opposition from Comsat, the ATA, the Congress, and OTP.

a. Negative reaction—industry.—Comsat disagreed with the proposal because corporate research and development funds, which were invested on the basis of published and reaffirmed U.S. policy of leased services rather than Government ownership, would have been wasteful.[22]

b. Congressional reaction.—Members of Congress also raised objections to the plan. In addition to favoring U.S. participation by a private entity rather than a Government agency, several Members objected to the prospect that ESRO would have had veto powers over the Pacific system where U.S. airliners dominated, as well as

---

million in 1972. (Department of Transportation and Related Agencies Appropriations for Fiscal Year 1974. Committee on Appropriations, Subcommittee on Department of Transportation and Related Agencies Appropriations. U.S. House of Representatives, 93d Congress, 1st Session, Apr. 2, 1973 (Washington, U.S. Government Printing Office, 1973).

[17] Klass, Philip J. Joint Aerosat to Be Sought to Avoid ICAO Argument. Aviation Week and Space Technology, Apr. 12, 1971, p. 17.

[18] Europen space policymaking body; members: Belgium, France, Germany, Italy, Netherlands, Spain, Sweden, Switzerland, United Kingdom.

[19] "Aerosat Progresses. But Obstacles Remain," Aviation Week and Space Technology, Aug. 23, 1971, p. 35–36.

[20] Problem of U.S. private company dealing with European government-owned communications companies.

[21] "Comsat Appeals to Nixon on Plan for U.S. Satellites," Washington Evening Star, Nov. 24, 1971.

[22] Dense, Michael. IATA Against New Navigation Scheme, The Financial Times (London). May 24, 1971; A Problem of Control, Flight International, Apr. 6, 1972. p. 474–475.

the Atlantic, and to the fact that the FAA/ESRO agreement would necessarily result in the export of advanced U.S. technology.[23]

11. Nixon administration rejection of FAA/ESRO plan

On February 9, 1972, the Nixon Administration announced its decision to renegotiate the agreement.

[White House letter:]

[Copy]

THE WHITE HOUSE,
Washington, D.C., February 5, 1972.

For: The Secretary of State and The Secretary of Transportation.
Subject: Aeronautical Communications Satellite (AEROSAT).

After careful consideration of your memoranda of December 17 and 16, respectively, and a review which took into account domestic and congressional as well as international considerations, the President has decided that the proposed FAA/ESRO Aeronautical Satellite Program as set forth in the draft Memorandum of Understanding is not in accord with Administration Policy and should be substantially redirected.

The President has instructed the Director of the Office of Telecommunications Policy to coordinate the implementation of his decision by providing an updated statement of policy in this area, and by undertaking responsibility for the substantive portion of the reopened negotiations for aeronautical satellite services.

In conveying the decision to European and other foreign governments concerned, every effort will be made to reassure these governments that the United States fully supports international cooperation in space even though it cannot accept the specific proposals contained in the current draft FAA/ESRO Memorandum of Understanding. The Secretary of State will inform these governments, with the specific form of the notification coordinated with the Director of the Office of Telecommunications Policy.

HENRY A. KISSINGER.

Nor did the White House approve of the arbitrarily selected procurement arrangements. Rather, a system based on an international competition to select the entity to develop the hardware and services on the basis of the best combination of price, quality, and delivery (which favored U.S. industry) was preferred.

In addition, the administration wanted control of the system to be based on actual use, which would result in European and U.S. control over North Atlantic operations and U.S. control over Pacific operations.[24]

12. European reaction

When ESRO signed the agreement with FAA, the European group changed its charter to include development of applications payloads, voted a sizable 3-year budget for applications projects covering the years 1972–74 and approved a provisional budget for 1975–77 to insure continuity in programs such as Aerosat. In addition, the ESRO-member nations which were participating in the program signed a formal agreement giving the Director General authority to sign a final memorandum of understanding with FAA and start planning design contracts with the European space industry, using funds from the 1972 budget.

The Europeans were thus understandably shocked when the agreement was invalidated. The immediate European reaction was to have ESRO proceed independently with phase 2 studies for its own system. ESRO gave White House officials until the fall of 1972 to decide whether or not there would be an international program. The phase 2 studies were expected to be completed by the end of 1972. If ESRO were to proceed unilaterally, it needed to select a winning consortium.[25]

---

[23] Senator Warren Magnuson, Congressional Press Release, 92-172, Feb. 16, 1972.

[24] Johnsen, Katherine. "U.S. to Press for Private Entity Aerosat," Aviation Week and Space Technology, Feb. 21, 1972, p. 17.

13. Alternative proposals

The Administration was therefore left with several decisions: (1) whether the United States should participate in an international Aerosat program, (2) whether the U.S. Government should own its portion of the system or lease it from a private commercial company, and (3) what the size and pace of the program should be. During the months which followed the White House announcement, numerous proposals for an Aerosat system were presented on the OTP.

a. Comsat.—Comsat offered a plan patterned on the Intelsat global network. The initial preoperational program would be of minimum size, providing service in a single ocean area. The follow-on operational program would function on the principle of investment related to use and voice (on policy) related to investment. All jointly owned hardware could be procured on the basis of bona fide international competition with no direct proportion to any geographic area. Comsat would be the designated entity to represent U.S. interests in the system.[26]

b. ATA.—The ATA proposed a unilateral, experimental small-scale, one-ocean [Atlantic] hybrid satellite system. A unilateral approach was favored since it was believed that its approach would hasten the establishment of a system. The subsequent operational system would of necessity be an international venture. ATA favored NASA as the lead agency, hoping to minimize program delay due to the controversy over private vs. Government ownership of the system.[27]

c. ICAO.—In an effort to appease the airlines, the ICAO proposed an Aerosat program which was designed to assure air carriers that they would not be forced to pay for an expensive communications satellite system. Government assurances that the cost of the system would not be recovered directly or indirectly from the users was incorporated into the proposal. In addition, airline participation in the program was to be strictly voluntary. The term "preoperational" was dropped in favor of a phase 1 "evaluation and development" Phase, thereby not preordaining the existence of an operational system.[28]

---

[25] "U.S. Indecision on Aerosat Plans Spurs Impatience of Europeans," Aviation Week and Space Technology, Jan. 10, 1972; "Solution Sought for Impasse on Aerosat," Aviation Week and Space Technology. Apr. 17, 1972, p. 16.

[26] "Comsat Offers Aerosat Patterned on Intelsat Global Network," Aviation Week and Space Technology, Jan. 3, 1972, p. 17.

[27] "ATA Urges U.S. Move Forward With Small-Scale Aerosat Test," Aviation Week and Space Technology, Apr. 17, 1972, p. 17. NASA's charter, unlike that of the FAA, has no provisions for NASA's operational management of a technology. Thus, some observers felt that by allowing NASA to manage the experimental phase of the program, no precedent for Government or private ownership was set. [Following the ambitious proposals sponsored by the FAA, the ATA had changed its position on who would be the best caretaker of its interests in a small experimental, evaluation program.]

[28] "ICAO Aerosat Plan Gets Airline Support," Aviation Week and Space Technology, May 15, 1972, p. 40.

14. Revised Nixon administration policy

None of these proposals was actually adopted. Instead, the Office of Telecommunications Policy invited ESRO to select a U.S. corporate partner with which it would be prepared to proceed on the development of a trial spaceborne system similar to that which was the subject of the original FAA/ESRO agreement.

ESRO responded by issuing a call for letters of interest from U.S. companies. It was also announced that the U.S. owner would not participate in the actual manufacturing of the spacecraft. The U.S. collaborator would pay half the development costs in return for a 50-percent ownership of the space segment, and would have responsibility for monitoring its space segment and leasing services to U.S. authorities. This policy reversed the previous situation whereby OTP insisted that a development contract was to be awarded on a competitive basis.[29]

15. Airline opposition to Nixon policy

At congressional hearings,[30] the ATA voiced strong opposition to the OTP plan. The airlines felt that the conditions which had led to the initial proposal for an AEROSAT seemed to be improved, thus precluding the need for an immediate implementation of a satellite communication system. The decrease in passenger traffic due to the economic recession in North America and Europe and the introduction of the wide-body jet had reduced the number of transatlantic flights.

The ATA claimed that the stated need for the FAA/ESRO program was based upon a requirement for augmentation of oceanic communications in the early 1980's due to a predicted saturation of high frequency [HF] communications. Airline studies indicated that such a saturation would not have occurred until late in the decade. Intelsat, used for fixed point-to-point communications across the world, was taking more and more of the traffic which had previously been sent via HF links. Additional channel space was therefore becoming available for mobile services. And, in December 1971, four extra HF channels were dedicated to air traffic control in the North Atlantic region. Furthermore, the single sideband technique, which reduces bandwidth requirements by almost half and greatly improves reliability and quality, was being used increasingly by airlines. By using the full potential of high frequency single sideband communications, the ATA asserted that there was not an immediate need for a satellite communications capability. Further, the full implementation of high frequency single sideband radio could be accomplished at considerably less cost to the airliners and passengers than a communications system predicated upon the use of an aeronautical communications satellite. The additional time made available by the use of interim technologies would give the United States the opportunity for an orderly investigation of technical and administrative alternatives.

---

[29] Klass, Philip J. "OTP Proposes U.S. Pick Aerosat Partner," Aviation Week and Space Technology, Oct. 16, 1972, p. 16.

[30] Department of Transportation and Related Agencies Appropriations for Fiscal Year 1974. Committee on Appropriations, Subcommittee on Department of Transportation and Related Agencies Appropriations. House of Representatives. U.S. Congress. 93d Congress, 1st session, Apr. 2, 1973. Washington, U.S. Government Printing Office, 1973.

Finally, the ATA once again protested the requirement for a surveillance capability on the basis that it was unnecessary for safety and added needlessly to the costs of the system. The ATA feared that foreign governments would have an undue influence over U.S. airline operations through Aerosat's administrative structure, and that they would be given the opportunity to escalate user charges in order to pay for their share of the system.

It was feared that the preoperational program would generate a momentum of its own, making it difficult if not impossible to modify or eliminate any feature.

16. ATA proposal

For these reasons, the ATA once again proposed a low-cost, single satellite experiment to be conducted by NASA. NASA management was preferred in order to keep the program on an experimental basis and prevent premature commitment by the Government to a follow-on program.

Other nations could participate in the program, but the project was to be funded and managed by the United States. The organization also insisted that VHF technology was adequate for airline needs and therefore should be the preferred frequency.[31]

ATA was joined by IATA, ICAO, and the British Civil Aviation Authority.[32, 33]

17. Congress deletes Aerosat funds

The House of Representatives on June 20, 1973, affirmed its Appropriations Committee recommendations and passed overwhelmingly a Department of Transportation fiscal 1974 appropriations bill which deleted all money for aeronautical satellite system research and development. The FAA was told to obtain the support and cooperation of the potential users of the system before proceeding further with the program.[34]

---

[31] "ATA Opposes FAA/ESRO Aerosat Plan," Space Business Daily, Mar. 19, 1973; Klass, Philip J. "ATA Opposes Joint Program on Aerosat," Aviation Week and Space Technology, Mar. 26, 1973, p. 26.

[32] "CAA Moves Toward Industry Position on Aerosat, Aerospace Daily, May 3, 1973, p. 18–19; "Atlantic Satellite—Plans Too Costly, Say Airlines," Michael Donne, the Financial Times (London), May 5, 1973, p. 13.

[33] In response to the ATA criticism of the FAA/ESRO proposal, David Israel, Director of FAA's Office of Systems Engineering Management, testified before Congress that since a lead time of 10 years is necessary to determine the requirements of an operational system, current FAA planning was not premature. He stated that abandonment of the AEROSAT project would have detrimental effects for the United States since such a course of action would lead ESRO to proceed alone with its own system in which the United States would have no voice in developing or implementing. In addition, Mr. Israel asserted that an operational aeronautical communications satellite system would cost less to operate yearly than the existing system with its duplicative facilities. He then pointed to examples of gross navigational errors made by airliners over the North Atlantic and reiterated the need for surveillance capability for safety. He further noted that two satellites were needed not only for surveillance purposes, but also for reason of reliability in the event that one should fall. The airlines, however, remained steadfast in their opposition. Department of Transportation and Related Agencies Appropriations for Fiscal Year 1974, Committee on Appropriations, Subcommittee on Department of Transportation and Related Agencies Appropriations, U.S. House of Representatives, 93d Congress, 1st session, Apr. 2, 1973 (Washington, D.C., U.S. Government Printing Office, 1973); "ATA Opposes Joint Program on Aerosat," Philip J. Klass, Aviation Week and Space Technology, Mar. 26, 1973, pp. 26–27.

[34] Report to accompany H.R. 8760. Department of Transportation and related agencies appropriation bill, for fiscal year 1974. Report No. 93–285, House Committee on Appropriations, House of Representatives, U.S. Congress, 93d Congress, 1st session, June 13, 1973. Washington, U.S. Government Printing Office, 1973, p. 18.

18. Congress restores Aerosat funds

The funds were later restored in conference committee with the proviso that a formal presentation be made by the Department of Transportation [FAA] prior to agreeing to any satellite program with foreign governments which entailed Federal support.[35]

19. FAA, airlines negotiate a compromise agreement

Between April and July of 1973, the FAA reviewed the proposed Aerosat program with U.S. airlines and reached a compromise agreement. Under the terms of the compromise, only two Aerosats would be built, instead of three, and both would be equipped to operate at VHF as well as L-band.

In order to ensure the experimental nature of the program, it would be stated in the revised draft memorandum of understanding that the evaluation program itself is not a commitment to deploy an operational system or to define the future characteristics of such a system. Also, in recognition of the airlines' concern that the countries participating in the Aerosat evaluation program would seek to recover their share of the program cost via user charges, the U.S. proposal would include a specific ban on such recovery.[36]

Another change reflected by the new proposal was the minimization of overall Aerosat program costs by reducing by half the number of Aerosat earth terminals on each side of the Atlantic.

As a result of these negotiated changes in the program, the airlines, through the ATA, withdrew their objections.[37]

20. Renewed FAA/ESRO negotiations

Agreement to the program was not reached too soon. When the ESRO Aerosat Program Board met on July 4, 1973 in Paris, there was strong sentiment to proceed with a unilateral European-Canadian Aerosat program because of delays and uncertainties in the U.S. position. However, it was decided to give the U.S. Government until the end of July to reach a firm policy and make a commitment. The FAA presented its proposal to Congress for approval. Congressional endorsement came less than an hour before the deadline.[38]

a. ESRO modification of technical requirements.—In November 1973, ESRO officials met with FAA representatives and informed them that ESRO was holding to an earlier design requirement that the satellite have five usable L-band transponders at the end of its life. (FAA officials had expected ESRO to bargain for four.) ESRO permitted the FAA to have the two VHF channels it requested, but only in addition to the full complement of UHF channels. It thus became apparent that the satellite would require a more powerful launcher.[39]

---

[35] Conference Report on Department of Transportation and Related Subjects, to accompany H.R. 8780. Report No. 93-426, July 31, 1973. Washington, U.S. Government Printing Office, 1973, p. 6-7.

[36] Article 8, Financing and Cost:

No. 4. None of the costs of the joint Aerosat evaluation program shall be recoverable concurrently or subsequently, directly or indirectly, by charges imposed on aircraft operators.

No. 5. None of the costs of the added experimental capability shall be recoverable concurrently or subsequently, directly, or indirectly, by charges imposed on aircraft operators.

[37] It is significant that the ATA did not advocate the program, but merely withdrew its objections.

[38] Klass, Philip J. "Europe to Study New U.S. Aerosat Plan," Aviation Week and Space Technology, Aug. 6, 1973, p. 17.

b. NASA devises new launcher policy.—However, NASA policy allowed access to the Delta 3914 launcher only to U.S. domestic communications satellite companies. NASA decided to allow Delta uprating only as an exception to an earlier judgment which forbade uprating current launchers because the space shuttle would supplant them in the 1980's. The exception was made on behalf of U.S. domestic satellite communications companies, which were allowed to enter agreements with Delta builder McDonnell Douglas Astronautics, Co. Two RCA subsidiaries did so to get the program started. NASA had barred other potential users from this arrangement because wider participation could have created pressure on NASA to salvage the program if it experienced problems. After several negotiations with the FAA, NASA was persuaded to launch Aerosat with the Delta 3914.

21. Memorandum of understanding signed

In late December 1973, the FAA announced that it had negotiated a draft memorandum of understanding with ESRO. The official Memorandum of Understanding [MOU] was signed in August 1974 by the United States, Canada, Belgium, Denmark, France, West Germany, United Kingdom, Italy, the Netherlands, Spain, Sweden, and Switzerland.

The MOU provided that the spacecraft and ground facilities directly related to the control of the satellite's orbital characteristics and status were to be the responsibility of a Space Segment Program Office jointly organized by ESRO, Canada, and the U.S. industrial partner. Ownership of the space segment was to be divided as follows: United States, 47 percent; ESRO, 47 percent; and Canada, 6 percent.

User ground facilities, aircraft avionics and the test program were to be managed by ESRO, the FAA, and Canada through an Aerosat Coordination Office. The office would be responsible for design, manufacture and operation of an Aerosat communications center and Aerosat earth terminals, for the operation of several suitably equipped experimental aircraft, and for the preparation and execution of a test program.

Pursuant to the agreement, ESRO chose as its U.S. industrial partner Comsat General Corp.

22. Program termination

As time passed, the Aerosat program was beset with schedule delays, legal and financial difficulties and increasing congressional dissatisfaction.

a. Denial of fiscal year 1976 funds by Congress.—In 1975, the House Appropriations Committee cut Aerosat funds for fiscal year 1976 because the committee felt that the VHF frequency would receive an unfair evaluation and that the L-band frequency had already been chosen for operational use. After testimony by the FAA assuring fair evaluation of the two frequencies, the funds were restored by the Senate Appropriations Committee, and later by both Houses.

---

[39] "FAA Seeks Aerosat Flexibility," Aerospace Daily, Nov. 28, 1973, p. 145.

b. Comsat dispute.—In late 1975, there arose a contract dispute between Comsat and the FAA over the cost of the system development and leased services, causing yet another delay in the program. A compromise was reached several months later.

c. Congressional opposition.—In February 1976, at a hearing of the Subcommittee on Transportation, Aviation, and Weather of the House Committee on Science and Technology, Chairman Dale Milford questioned the validity of the increasingly expensive Aerosat Program in view of other higher priority R&D programs.

This served as a prelude to the action by the same committee 1 year later to veto Aerosat development funds and study less expensive alternative programs.[40]

---

[40] Pertinent part of committee report:

The FAA requested $15,562,000 for the Aerosat program in its fiscal year 1978 budget proposal. The agency also informed the committee that the total cost of the program would be $168.1 million. This is well above last year's projection of $125 million.

Even before it became aware of this large funding increase, the committee was deeply concerned about the advisability of proceeding with the Aerosat program. The committee has had serious reservations about the manner in which the American co-owner of the satellite system was selected, the direction afforded by the Office of Telecommunications Policy, the financial arrangements between the U.S. Government and Comsat, and the willingness of all parties to or who are directly affected by the Aerosat program to continue with the presently structured program.

Notwithstanding these considerations, an even greater factor affecting the committee's decision was that of the changing conditions of transoceanic aircraft travel. The advent of the jumbo jet, spiraling fuel costs and a general economic recession have combined to greatly reduce the trans-Atlantic travel levels that were projected at the inception of the program. Testimony before the committee revealed general agreement that the traffic projections have not materialized and that a much more modest rate of growth is expected in the future. Yet the very rationale for proceeding with Aerosat, as stated by the Office of Telecommunications Policy in 1971 was premised on "the rapid increase in aircraft density on international routes and the limitations of existing communications systems."

Because the traffic has not materialized as projected, the committee believes that this rationale can no longer be totally justified. However, the committee is also sensitive to the international implications of the program and aware of the fact that it would take many years of negotiation to assemble another Aerosat program in the future.

By virtue of its jurisdiction over NASA, the committee has had much experience with the complexities of such international negotiations and gives the highest weight to this aspect of the Aerosat program.

The committee, considering all of these factors, recommended in 1976 that Aerosat should be continued only if it did not adversely affect other, more critical FAA R&D programs. In that same year, the committee recommended that FAA R&D program funding level be increased to $85 million, and that future Aerosat funding be in addition to this basic funding level.

Unfortunately, only $70 million was approved as a basic funding level by the Office of Management and Budget, and critical programs must be deferred in order to make allowance for Aerosat.

Even more unfortunate, in the view of the committee, is that Aerosat funding is projected to be $25 million per year, or one-third of the FAA R&D budget, for the next six years.

The committee, without equivocation, believes that there is absolutly no way that the FAA can meet this funding schedule and still fulfill its designation responsibilities in critical areas of aviation R&D. The Aerosat program, on the U.S. side, is a culmination of the efforts of numerous Government agencies and departments. Yet, as the program decreased in value, and increased in cost, each agency and department politely passed the buck to the FAA R&D program. This is unacceptable to the committee. The committee believes that the current Administration should immediately reevaluate the Aerosat funding mechanism, as well as conduct an examination of the merits of the program through the Aerosat Council. To support this reevaluation, the committee has authorized the FAA to expend up to $1,500,000 for a feasibility study of the Aerosat program.

Therefore, until a more satisfactory funding plan is proposed, the committee cannot in good faith authorize the Aerosat program. However, the committee will consider additional or supplemental legislation if such a plan is forthcoming from the Administration.

The committee further urges that the Administration submit its plan to the committee, so that the committee may act upon it well in advance of the next schedule meeting of the Aerosat Council (May 4).

As a final note concerning the Aerosat Program, the committee received a letter from the House Committee on Interstate and Foreign Commerce which stated in part that that commit-

Continued

This recommendation was later adopted by the Senate. In effect, the Aerosat program, as such, was terminated with the cancellation of U.S. funding, though one million dollars were appropriated for fiscal year 1978 to permit the FAA to conduct a feasibility study on alternative programs.

At the Aerosat Council meeting on September 15 and 16, 1977, the United States officially informed the council that it did not have the funds to proceed with the Aerosat program. The United States did propose that a special committee be established by the council to reevaluate system requirements. At a subsequent Aerosat Council meeting (Jan. 18-19, 1978) the council agreed to establish such a committee.

Since that time, the Aerosat Council committee has met six times and has held 22 working group sessions involving participants from a number of nations (including the United States) and international organizations. A major study on how Aerosat program type requirements could be met without engaging in a large development program is being completed by the Aerosat Council committee. The study report, anticipated for the end of 1981, will contain conclusions and recommendations on how aeronautical communication needs can be met. Volume 3 of the four-part study will be the FAA-funded feasibility study on alternative programs.

C. AEROSAT SYSTEM DESCRIPTION

The Aerosat experimental and evaluation system was designed to provide the communication functions necessary to evaluate performance of voice and data communications between ground and aircraft, to experiment with aircraft surveillance capabilities, and to develop operational standards and practices. The satellite facilities were to be shared by all participants, and the ground facilities and airborne systems were to be provided by individual participants.

1. Overall Aerosat system

The joint Aerosat evaluation program consisted of a space segment program and a coordinated program.

---

tee has "serious reservations about the need for (Aerosat) * * * and doubts as to whether the continuation of the program as it is now envisioned is in the public interest."

This committee is not able at present to comment on the objections proffered by the Commerce Committee. However, the committee is taking this under advisement and strongly recommends that any Administration examination of the Aerosat program and subsequent proposal to this committee take into account the concerns of the Commerce Committee.

In the interim, the committee strongly recommends that the following programs be implemented or accelerated in lieu of Aerosat:

(1) Major System Development, $5 million. To include improvements in the Flight Service Station modernization program and Terminal Information Processing System and to fulfill FAA commitments in the Microwave Landing System [MLS] program.

(2) Airport/Airway Technology, $5 million. To improve the aviation weather programs, to accelerate the airport payment program, and to launch a major effort to assess future communications needs of the entire FAA organization.

(3) Advanced System Development and System Engineering, $5 million. To improve ATC computers, accelerate efforts in human factors research, including Airborne Traffic Situation Displays, and accelerate efforts in studying and simulating future airport systems configurations and capacity limitations.

"Authorizing Appropriations to the Federal Aviation Administration for Research and Development," Report No. 95-95. Committee on Science and Technology, U.S. Congress, House of Representatives, 95th Congress, 1st session, Mar. 18, 1977. Washington, U.S. Government Printing Office, 1977.

a. Space segment program.—The space segment was to be provided jointly by the United States, Europe, and Canada. It was to comprise two geostationary satellites positioned over the Atlantic Ocean and a Satellite Control Facility [SCF]. The FAA would have leased its portion of the space segment capability from Comsat who was to own the space segment jointly with ESA and Canada. This arrangement complied with a U.S. policy of reliance upon the private sector for ownership of common carrier communication facilities. In addition, to meet the U.S. airlines' evaluation requirements, VHF channels would have been added to Aerosat to permit a comparative evaluation with L-band.

b. Coordinated program.—The coordinated program was to consist of a ground segment, an airborne segment, and a test program. It contained three basic elements:

> Several kinds of telecommunications ground facilities: the major ones designated as aeronautical services earth terminals [ASET] and aeronautical satellite communications centers [ASCC];
>
> Aircraft avionics; and
>
> Coordinated test, demonstration, and evaluation program.

The ground and airborne segments would have been developed and financed individually by each participant with test programs closely coordinated by the Aerosat Coordination Office under the direction of the Aerosat Council, but separately conducted by each country. The airborne segment included two major ground stations: one in Europe, provided by Europe, and one in North America, provided by the United States and Canada.

2. Space segment

The Aerosat program was to utilize two geostationary satellites as radio relays between ground facilities and airborne participants. The two satellites would be deployed to provide Atlantic Ocean coverage and would be stationed approximately 15 and 40 degrees west longitude. Communications and surveillance tests were to be carried out in three frequency bands as follows: C-band between satellite and ground stations, L-band between satellite and aircraft, and VHF between satellite and aircraft. The second satellite would enable evaluation of independent surveillance techniques employing range measurements.

The satellites were to be supported by a Satellite Control Facility [SCF] that would perform orbit determination functions and tend to stationkeeping, housekeeping, and necessary operational controls via a radio link between the control facility earth terminal and the satellite. The facility was to monitor satellite operation in geostationary orbit and during positioning/repositioning maneuvers, command the satellites' orbits to the required accuracy, provide channel status information, provide antenna pointing information, and provide satellite position information.

3. Ground segment

Users of the Aerosat system were supposed to provide ground facilities to enable communications between ground stations and aircraft via the satellites. Each organizational entity constituting a primary participant in the Aerosat system was to provide one or two ground facilities, including an Earth terminal, a control center, interface with user stations, and test systems.

The Aeronautical Services Earth Terminal [ASET] was to provide reception and transmission of communications on the satellite links, and to interface with ground users via an Aeronautical Satellite Communications Center [ASCC] which was to supervise the use of communications services for all ground users desiring access through the ASET serving a given region. Test and monitoring of satellite communications was to be provided by an Electronic Test Set [ETS] that included receiving and transmitting capabilities similar to an aircraft avionics set.

4. *Airborne segment*

Each Aerosat user was to arrange for obtaining and equipping test or cooperating aircraft to provide air terminals as required for evaluations and experiments. Avionics system and subsystem configurations were supposed to be designed to allow technical and operational performance evaluation of a number of techniques for voice and data communications between ground and aircraft, experimental evaluation of surveillance concepts, evaluation of various access control techniques, and a comparison of VHF and L-band frequencies for satellite communications.

D. ORGANIZATIONAL STRUCTURE/INSTITUTIONAL ARRANGEMENTS

The Memorandum of Understanding [MOU] between the U.S. Department of Transportation (Federal Aviation Administration), the European Space Research Organization [ESRO],[41] and the Government of Canada defined the joint aerosat evaluation program. The MOU was signed by Canada and ESRO on August 2, 1974, following earlier signature by the FAA on May 9, 1974.

The Aerosat Council had the primary responsibility to the MOU signatories for the execution of the joint Aerosat evaluation program. It was comprised of up to six representatives designated by the FAA, up to six by ESA, up to three by Canada, and one by any future participant in the program. The council was to coordinate the aeronautical interests of owners and users of the system, approve the experimental and evaluation programs arranged and coordinated by the Aerosat Coordination Office, maintain close contacts with the civilian aeronautical organizations and maintain adequate liaison with the ICAO on questions of mutual interest relating to the experimental and evaluation program.

The Aerosat Coordination Office [ACO] was to report to, and recieve guidance and instructions from, the council with respect to the program in accordance with provisions of the MOU. This office was to have the day-to-day implementation responsibility for the coordinated program.

The space segment capability of the joint Aerosat evaluation program was planned to be coowned by ESA (47 percent), Comsat General Corp. (47 percent), and the Canadian Government (6 percent). Comsat General Corp. was to lease its share of the space segment to the FAA.

---

[41] Now known as the European Space Agency [ESA].

The Space Segment Board was to be the governing body responsible for provision of an aeronautical space segment capability. It would have given policy direction to the Space Segment Program and would have been comprised of three representatives of ESA and of the Comsat General Corp., and one representative of the Canadian Government. The Space Segment Program Office was to be established under the guideane of the Space Segment Board to execute the Space Segment Program.

E. POLICY ISSUES

Though the Aerosat program was not, in the end, sustained with funding by the United States, the program history displays a number of issues which may be relevant to future space applications programs. The Aerosat program was replete with complex problems and competing philosophies which plagued the progrm until its collapse. An examination of the issues involved may aid in devising a more successful resoluton to these problems for future programs.

1. Technological advance versus user requirements

From the inception of the program, the airlines, as the principal users of the system, stated the need for a simple aeronautical communications capability. They were chiefly concerned with minimizing cost and complexity. They therefore preferred a VHF satellite because they through a VHF system and associated hardware would be cheaper, faster to implement, and adequte for their needs.

Scientific concerns, however, centered on developing the most advanced aeronautical communications technology, intended to meet projected as well as current requirements. Such an advanced system necessarily results in increased system costs.

At first glance, the Aerosat program represented a compromise between these two positions. When the airlines were assured that they would not have to pay directly or indirectly for the costs of the evaluation program, they withdrew their objections to Aerosat. However, when it appeared that the costs of the program were steadily increasing and that the system could only be established at the expense of other R&D programs for which they felt they had a more immediate need, they reinstated their objections.

How should such competing interest be reconciled? Should the users determine the characteristics of the proposed system, thereby making the users' ability to pay the determining factor in technical design? Are there space applications technologies which are of sufficient public value so that they should be subsidized? Does the Federal Government have an interest in the development of Aerosat-type capabilities in terms of safety and improved communications? If so, is this interest sufficient to warrant Federal subsidy in those cases in which the user cannot afford to pay for the development of a sophisticated technology? Is extremely sophisticated technology necessary to meet the majority of user needs?

2. Institutional organization

An examination of the history of the Aerosat program reveals an institutional disorganization which existed up until the signing of the Memorandum of Understanding. Initially, there was uncertainty over which Federal agency was responsible for the development of Aerosat. Due to the confusion concerning which agency should develop an experimental capability and by what process the system would eventually become operational, the FAA and NASA alternately negotiated with ESRO until 1971. At several points during the conduct of those negotiations, the Europeans made agreements concerning Aerosat only to find those agreements negated by other branches of the Government. This course of action left the Europeans bewildered.

Is there a need for organizing institutional responsibilities and resolving bureaucratic conflicts in Federal policies before commencing negotiations with foreign governments? Can some mechanism for coordinating Federal policies be established? Does the United States need to establish firmer guidelines on what branch of the Government or which organization may make commitments for the United States?

3. Foreign relations

Since the Aerosat program was to be international cooperative effort, its development necessarily impacted on U.S. foreign relations.

a. Foreign cooperation versus technical expediency.—Had the United States proceeded to develop an Aerosat system on a unilateral basis, a VHF system could presumably have been implemented in the 1970's. However, in an effort to cooperate with the Europeans and to accommodate the Europeans' desire for technical cooperation and their preference for L-band technology, the United States modified its program specifications, resulting in delays and dissatisfaction within the user community.

Should the United States have proceeded on a unilateral basis and subsequently invited other nations to participate in our program, thereby forcing them to choose our technology or develop a competing technology?

The Aerosat program with its efforts to achieve international consensus and participation in technical development contrasts markedly to the implementation of the Intelsat system where the United States forged ahead with the development of a space communications technology which was subsequently offered to others. Is there a middle ground between these two extremes which can be reached? Does international participation necessarily result in lengthy delays in system implementation? Can this situation be avoided? When the interests of foreign nations conflict with those of various U.S. interest groups, whose concerns should be given greater weight in policy decisions?

b. International agreements.—The United States signed the Memorandum of Understanding establishing a joint Aerosat program in 1974. The Europeans and Canadians then operated on the assumption that the United States had committed itself to the Aerosat program. What was the impact on foreign relations of this program's cancellation? How has this decision affected other programs and future agreements? Should the United States regard an international agreement as binding and inviolate? Or, if the circumstances upon which the agreement was based change subsequent to the agreement, does the United States have a justifiable basis for rescission? Should economic concerns prevail over foreign relations?

4. Technical obsolescence

The Aerosat program was first suggested in the 1960's and it gradually evolved throughout the early 1970's. The technical specifications remained virtually unchanged after 1974. If the United States had proceeded with the program would the technology have been obsolete by the time of its implementation? If so, how can the lead time from idea to implementation be reduced to avoid the possibility of space technology becoming out-dated prior to implementation?

5. Summary

The history of the Aerosat program raises numerous questions of policy. Though the final decision was to cancel the program, its example may still serve to focus on the problems involved in implementing other space applications technologies. Primarily, it seems that space technology has generally progressed further than the institutional arrangements which are necessary for its implementation. In order to gain the maximum benefits from space applications technologies, problems must be anticipated and conflicts resolved before the proposed technology reaches the implementation stages. Identifying the areas of conflict is a necessary first step in this process. However, by far the most difficult task, that of assigning relative priorities and values, lies ahead.

V. MARITIME COMMUNICATIONS SATELLITES

A. INTRODUCTION

The contrast between the widespread acceptance and use of advanced telecommunications ashore and the continuation of manual low capability systems for ships at sea is remarkable. There are many new and expensive ships which are equipped with hand-keyed telegraphy equipment as their primary communication device. These primitive mobile maritime communications have serious shortcomings which interfere with efficient maritime fleet management operations. Saturation of existing facilities during some periods of the day has already been approached. The size of the world's commercial fleet is rapidly increasing. There were almost 20,000 merchant vessels over 1,000 gross tons in 1970.[42] By 1979, the latest year for which there are data, that number has risen to almost 24,800.[43]

With traditional maritime communications systems, the average delay in communications traffic is 8 hours, with delays of 12 hours not unusual. And, once contact is made, voice quality is often poor. There are also radio blackouts, interference, and fading which limit effective radio time and traffic. Few industrial plants costing $25 to

---

[42] Irwin M. Heine. "The U.S. Maritime Industry in the National Interest." Published by the National Maritime Council, 1980, p. 259.

[43] U.S. Department of Commerce. Maritime Administration. A Statistical Analysis of the World's Maritime Fleets. Current as of Dec. 31, 1979. Published June 1981, p. vi.

$100 million are operated with the almost complete lack of reliable and available communications with management that is said to characterize most maritime operations. In the opinion of many maritime authorities, the traditional maritime radio communications system is inadequate, especially in emergency situations, and will become decreasingly useful with time.

Maritime satellites can overcome problems by providing a means for direct point-to-point high quality transmissions which are largely independent of the conditions of the propagation medium and which therefore can usually provide a rapid, reliable service for 24 hours per day. And, while satellite communications cost more than traditional maritime radio services, the cost may be a secondary consideration in view of the prospect that conventional systems will not have the capability required.[44]

Ideally, a maritime communications satellite system would be global and would include all seafaring nations in a single cooperative and cost-sharing entity. Such a system [Inmarsat] was the subject of international meetings between 1966 and 1976. In 1976 a convention establishing the International Maritime Satellite Organization [Inmarsat] was opened for signature. The convention has since entered into force, and Inmarsat will begin commercial operations in 1982. Inmarsat currently has 35 members (plus the Byelorussian S.S.R. and Ukrainian S.S.R.). These are identified in table 3.

Meantime, a U.S. maritime communications system of a lesser scope has become a reality with the beginning of Marisat activities in 1976. The three Marisat satellites have provided virtually global maritime communications coverage since that time. The customer base of Marisat is expanding rapidly and Inmarsat will take this over when it becomes operational. The advent of the international consortium is anticipated to revolutionize maritime communications techniques and eventually replace all traditional maritime communications. Whether this will happen depends on economics, i.e., whether Inmarsat can operate successfully as a commercial venture, whether the customer base does indeed expand as anticipated, and whether Inmarsat users can afford the price of the shipboard equipment and the price of services. The following sections detail the Marisat program and the Inmarsat plans.

B. MARISAT

Despite the growth in maritime communications traffic and the dramatic increase in global commercial shipping tonnage, prior to the launch of Marisat 1 in 1976 mariners still relied on communications techniques essentially unchanged over the past 75 years—medium and high frequency [MF and HF] radio, and Morse code telegraphy. The results of using these outdated means of communications were hours of delay, congested frequencies, poor quality communications, and unreliable transmission depending on weather and atmospheric conditions. The U.S. Marisat system is now in its fifth year of providing fast and dependable communications, unaffected by weather or ionospheric conditions, 24 hours a day.

---

[44] "Maritime Satellites Are Here," H. A. Feigleson, U.S. Department of Commerce, AIAA paper 75-279. AIAA 11th annual meeting and technical display, Feb. 24-26, 1975.

1. History

The Marisat program was the result of a gap in the U.S. Navy satellite program. With the expected demise of the TacSatCom in the Pacific and the Lincoln Experimental Satellite-6 [LES–6] in the Atlantic, and the delay in their replacement by the Navy's FleetSatCom satellites, there arose a need to fill the anticipated gap in ship-to-shore naval communications. The Navy requested Comsat General Corporation to submit a proposal for a maritime communications satellite system to fill this gap.

The Navy's requirement for service on this system was expected to be of limited duration. In addition, initial satellite design studies revealed that the Navy demand would not utilize the full capacity of the satellites which could be orbited by existing launch vehicles. A reasonable and economical way to realize full satellite capability was a sharing arrangement with another customer. Consat's search for other potential users focused logically on the international maritime industry.

As a result, Comsat General decided to develop an integrated satellite system which could meet the requirements of the U.S. Navy on its assigned frequencies, as well as those of commercial shipping on newly available frequencies in the L and C bands. In this way Comsat General could fill the Navy's initial limited needs and provide for the gradual transfer of satellite capacity to commercial maritime service as the Navy's use diminished or terminated.

The Navy accepted the Comsat General proposal. After some initial problems in combining the two required frequency ranges, system designs were finalized and contracts were awarded.[45]

Marisat 1 was launched on February 19, 1976. The frequency allocated for Navy use (approximately 75 percent of satellite capacity) entered into military service on March 25. The civilian frequencies, however, were jammed.

After 3 weeks Comsat General engineers traced the problem to a component known as triplex filter. They decided that metal debris, created when the filter was screwed on, had clogged the filter. To free the filter of this debris, engineers increased the satellite's rotation rate from 60 rpm to 90 rpm, assuming that centrifugal force would spin the debris away from the filter. It was a temporary success for as soon as the satellite was returned to 60 rpm, the debris floated back and again jammed the frequency. Finally, in an attempt to pitch the debris permanently into a corner, engineers successfully wobbled the satellite 5–10 degrees.

Commercial operations began dramatically on July 9, 1976. The Phillips Petroleum Co. of Bartlesville, Okla., had been trying for 4 days to warn its seismic survey ship *Deep Sea Explorer* to change course and not dock at a port in Madagascar, where it was in danger of being impounded during an insurance claims dispute. Marine radio and telegraph operators were unable to raise the ship due to poor atmospheric conditions. At virtually the last minute, a

---

[45] Hughes Aircraft Co. was selected to construct the satellite and Aeroneutronics Ford the Earth stations.

Phillips Co. official succeeded in contacting the ship through Marisat 1, only moments after the satellite had been officially cleared for commercial operation.

Marisat 2 was launched on June 9, 1976. Marisat 3 was launched October 14, 1976.

2. Spacecraft technology

Marisat is a spin-stabilized cylindrical spacecraft with a design lifetime of 5 years (although the Marisats are expected to be able to provide service beyond that time, possibly into 1984). It weighs about 720 pounds. The communications subsystems consist of five repeaters; a 480 kHz wideband UHF repeater, two narrow-band 24 kHz repeaters, an L-band to C-band repeater and a C-band to L-band repeater. The three UHF repeaters are used for Navy services and the other two repeaters are used for commercial services with transmission between the shore station and the satellite in the 6 and 4 GHz bands and transmissions between the ships and satellites in the 1.6 and 1.5 GHz bands.

Messages travel by ordinary telephone links to the shore stations, where they are beamed to the satellite for relay to the ship receiver. The routing is reversed from ship to shore.

3. Earth terminals

The shore stations for the Marisat system are located at Southbury, Conn., for operation of the Atlantic satellite, at Santa Paula, Calif., for operation of the Pacific satellite, and at Yamaguchi, Japan, for the Indian Ocean. There is also a satellite control and monitoring station at Fucino, Italy.

Each earth station is "network control" for commercial traffic in its region, assigning and releasing communications channels as required to permit access to the system by a large number of ships. Three 42-foot dish antennas are provided at each earth station to transmit and receive Marisat traffic and to provide for telemetry, tracking and control of the satellite by Comsat General's System Control Center in Washington, D.C.

4. Ship terminals

Mobile terminal units include an above-deck portion enclosed in a fiberglass radome consisting of a 4-foot stabilized antenna with ship motion sensors and gearless servo drives that automatically keep the antenna locked on the satellite at all times, and a below deck portion consisting of a communications console with telephone and teleprinter, a status and operating panel, antenna control unit and power supply.[46]

Ship terminals are designed for unattended automatic reception. The receiver is always on to allow the ship's terminal computer to recognize the ship's identification signal and to process incoming messages. Control of the terminal (frequency retuning, channel selection, message type) is also performed automatically upon command from the shore terminal.

---

[46] One reason commercial ships did not use communications satellites was the large and costly antenna required.

5. Marisat system coverage

The Marisats are located in synchronous orbit 35,800 kilometers above the Equator. Marisat 1 is positioned at 15 degrees west longitude to serve most of the Atlantic Ocean and the Persian Gulf. Marisat 2 is stationed at 176.5 degrees east longitude and serves most of the Pacific Ocean. Marisat 3, which is positioned over the Indian Ocean at 73 degrees east longitude near the Maldive Islands, serves as a spare for Marisat 1 and 2.

6. Marisat system costs and ownership

Procurement of the Marisat system cost about $40 million and launch of the three Marisats cost about $38 million.

Comsat General owns 86.29 percent of the Marisat venture with the remaining shares divided between the traditional suppliers of ship-to-shore communications, RCA Global Communications, Western Union International, and International Telephone & Telegraph World Communications. These latter companies provide the landline connection between users and Comsat's ground transmission stations on the east and west coasts. Comsat General serves as the system manager.

7. Marisat system services and costs to users

In addition to voice communications and telex service, Marisat provides facsimiles of manifests, drawings, daily reports, weather maps and other graphic material as well as a capability for data communications at 1,200 and 2,400 bits per second.

Earth stations and satellites are owned jointly by the Marisat system owners. Ownership of the ship terminals is, however, not shared. Terminals may be supplied by any company on a lease or sale basis directly to shipowners. Shipowners can buy a terminal and antenna for $50,000–$80,000 (depending on the equipment purchased). Costs for leasing ship terminals are a function of the length of the lease. For example, costs could range from a low of about $1,865 per month for a 5-year lease up to $5,500 per month for a month's lease. In addition, message charges are $4 per minute for Telex (down from $6 which was the original charge until 1978) and $10 a minute for voice channels. Rates for current ship-to-shore systems are about $5 a minute for voice, $2.50 to $4 per minute for Telex and 33 cents a word for Morse code.

Thus, although the long-term overall financial savings resulting from rapid and reliable martime communications are thought to be potentially significant,[47] the service charges for using Marisat are greater than traditional ship-to-shore communications methods. Because the maritime industry has been traditionally conservative in adopting technical innovations, the Maritime Administration sought to encourage the use of Marisat when it started into commercial operations by sharing the system's hardware costs with a half-dozen shipping companies.[48] The Administration spent $200,000 on the program.

---

[47] "Maritime Satellites: Proceedings of Symposium, April 1974." Journal of the British Interplanetary Society. October 1974, pp. 721–800.

[48] Including Prudential Lines, U.S. Lines, Pacific Far East Line, and Moore-McCormack Bulk Transport.

The Navy's utilization of the Marisat sytem began to decrease in 1979 as DOD's own satellite capability increased. During the period of peak Navy use, however, over 450 Navy ships communicated via the Marisat system. As the military use of the system decreased, Comsat General sought other users. By the end of 1980, ships of over 35 nations were using Marisat[49] and 542 commercial ships and offshore oil drilling facilities were equipped for operations with the system.[50]

In May 1981, the number of Marisat users was more than 650 ships and off-shore facilities equipped with Marisat terminals[51] a significant increase during a 3-year period from 100 users in 1978.[52] Though the largest category of users is tankers, Marisat also provides services to cargo ships, passenger ships, yachts, government vessels, seismic survey ships, oil-drilling platforms, and icebreakers. Though worldwide figures are not currently available, data for U.S. utilization of Marisat show that in 1979, Marisat carried about 40 percent of U.S. originated or terminated maritime telephone traffic and about 22 percent of U.S. originated or terminated maritime telex communications.[53]

Marisat is expected to be capable of providing service into 1984 so Comsat is looking for additional customers for the system. One such customer, the United Kingdom Royal Navy, has leased capacity in the Atlantic region satellite from 1981 to 1984. In addition, Comsat General has recently leased capacity on all three Marisats to Inmarsat. (See below for details.)

C. INTERNATIONAL MARITIME ORGANIZATION [INMARSAT]

1. 1975 conference to establish Inmarsat

a. Background.—The effort to create an international maritime satellite system was the project of the International Maritime Consultative Organization [IMCO]. IMCO, an agency of the United Nations, began considering the possibilities of a change to satellite communications for ships at sea in 1966. Frequencies were set aside for use by maritime satellites in 1971. In 1972 a Panel of Experts was set up by IMCO to examine the characteristics and operational requirements of a maritime mobile satellite system.

Under the auspices of IMCO, the Intergovernmental Conference on the Establishment of an International Satellite System [Inmarsat] met in London, April 23–May 9, 1975. One of the items on its agenda was the establishment of a permanent Inmarsat organization, comparable to the International Telecommunications Satellite Organization [Intelsat] that provides the space segment for operation with fixed land-based terminals. Inmarsat would be responsible for policy and financial control of the use of the space system for maritime communications.

Following three weeks of debate among 43 national delegations, it was decided to postpone the formation of Inmarsat at least until the next Inmarsat Conference in London, February 9-27, 1976. An intersessional working group was established to resolve the problems which arose during the discussions. The complexities in establishing an Inmarsat organization were summarized as follows:

---

[49] "Comsat Seventeenth Annual Report to the President and the Congress, 1980." p. 48.
[50] "Comsat Guide to Intelsat, Marisat, and Comstar Satellite Systems, 1981." p. 40.
[51] Marifacts, v. 7, No. 1, March 1981. p. 5.
[52] M. Mulcahy. "Transition from Marosat to Inmarsat is Expected to be Smooth in 1982." Sea Technology. May 1981. p. 17.
[53] Conversation with Comsat spokesperson, August 1981.

> The proponents of the proposed system seek a profitable multi-National management of an expensive satellite system with marginal investment attractiveness, serving a maritime industry inclined to conservatism and historically resistant to technological innovation. The political aspects are underscored by this initial attempt to link the United States and the Societ Union in a multilateral commercial exploitation of space, while simultaneously fashioning an agreement responsive to the maritime importance of diverse countries and to their hopes for development of aerospace expertise and export sales to counter traditional U.S. dominance.[54]

b. Areas of controversy.—The three major areas of disagreement at the 1975 meeting centered on procurement policies, the relationship between governments and designated entities, and the division of responsibilities between Inmarsat's Assembly and its Executive Council.

A variety of procurement policies had been proposed. Most formulations provided for the award of contracts based on established price, quality, and the most favorable delivery time. The proposals differed in the extent to which they would oblige the Council to take into account a need to stimulate and maintain worldwide competition in the supply of goods and services. While some nations favored emphasizing the need to stimulate worldwide competition as the primary criterion for contract awards, the U.S. position required the Council to take into account the need to maintain and encourage worldwide competition only if two or more bids offer comparable combinations of price, quality and delivery time. The Western European delegations as well as the U.S.S.R. objected to this policy since the United States had the technological lead vested in one or two large corporations and would effectively have had a supplier monopoly over less advanced international firms.

Another area of differences was the relationship between governments and the entities designated to represent each nation in the Inmarsat organization. The Soviet Union disapproved of designating a commercial company, rather than a government-owned body, as a representative in Inmarsat. The U.S.S.R. disliked the notion of private firms assuming governmental responsibilities. The United States, however, made its position clear: it could participate in a global maritime satellite communications system only if the system's institutional framework incorporated a provision for a government to designate a private, nongovernmental telecommunications entity to undertake financial, technical, and operational responsibilities on behalf of, and without any financial guarantee from, the designating government.

Many nations expressed the opinion that governments should remain responsible for all of the activities of their designated entities. U.S. representatives responded that while the U.S. Government itself could not directly assume operational responsibility, it would nevertheless expect to exercise close supervision, guidance, and control over the activities of its designated entity consistent with applicable domestic law. Citing the analogous situation in which the Communications Satellite Corporation [Comsat] represents the United States in Intelsat, the United States emphasized the pervasive regulatory powers in the Federal Communications Commission [FCC], the special powers conferred on the FCC and the President under the Communications Satellite Act, and the specific powers given to the Office of Telecommunications Policy and the Department of State in Executive orders delegating Presidential powers derived from the Communications Satellite Act. The United States attempted to reassure those delegations which expressed anxiety on the point that the entity would be free to take any action which it felt was appropriate irrespective of governmental concern. The U.S. Government intended to retain sufficient statutory power to assure that its entity acted in a responsible manner and remained under the control of the Government.

---

[54] "Operational Marsat—An Evolving Concept," Lt. Comdr. Robert E. Fenton, AIAA paper 75-282, AIAA 11th annual meeting and technical display, Washington, D.C., Feb. 24-26, 1975.

The division of responsibilities between Inmarsat's Assembly and its Executive Council was also a point of contention. The United States position was that the Assembly on which each member State would sit, and have one vote, should have the power only to make recommendations and express its views to the Council. In the Council, investors would have weighed votes proportional to their investment, and the Council would have the ultimate power to decide all matters of a technical, operational or financial nature and all questions related directly or indirectly thereto. However, a substantial number of other nations favored an Assembly as the supreme organ with broad policymaking powers on a one nation/one vote principle.

The delegates at the 1975 London conference had expressed a general desire for the establishment of an organization such as Inmarsat as soon as possible. For this reason they decided to meet again in London in February 1976.

2. February 1976 London conference—unresolved differences

After three weeks of intensive negotiation, it was decided to delay the adoption of a formal convention establishing Inmarsat due to remaining unresolved differences. Procurement policies were left to future decision by the established Inmarsat. However, designated entities, shareholding, and voting in the Assembly still created difficulties. Another problem entered into the debate when several nations wished to place reservations on several of the clauses.

a. Designated entities, shareholding, and voting rights.—Under the draft convention, a 22-person council would have been formed under an Assembly of Parties, which would set up the operational section of Inmarsat. The council would have had 18 shareholding members and four members selected geographically. The Soviet Union did not want to accord a commercial venture, as a designated entity, voting rights. They also insisted on one nation/one vote in the council. The United States insisted that its designated entity be allowed to vote on the council deliberations according to its shares, as is done in Intelsat, where the United States had (at that time) a voting unit of 40 percent in shares.

A compromise was tentatively reached when the United States dropped its shareholding ceiling demand from 40 percent to 30 percent. The Soviets then agreed to a 20 percent voting right. The matter ended, pending further instructions from Washington and Moscow.[55]

b. Reservations clauses.—This issue concerned whether or not the convention should state explicitly that signatories would enter no reservations to its provisions or be silent on this matter. The United States urged an explicit statement. Since the designated entity which would represent the United States would be a private entity, the U.S. position was that a private organization should not be expected to risk a considerable financial investment without the explicit assurance. The Soviet Union stated that it would enter no reservations but was opposed to an explicit provision.

The next conference was scheduled for September 1-3, 1976. At the September conference, differences were resolved.

3. Inmarsat convention opened for signature

The convention and operating agreement establishing Inmarsat to own and operate a global communications system for merchant shipping was opened for signature on September 3, 1976.

The convention was to be signed by the governments participating in Inmarsat and the operating agreement by the governments or by their designated operating entities. The terms of the convention provided that it would enter into force 60 days after being signed by nations representing 95 percent of the initial investment shares. However, the convention also had a provision that it would have to enter into force within three years of being opened for signature or it would be void. Inmarsat did come into existence on July 16, 1979, when 26 member States had signed the convention and operating agreement.

a. Administrative provisions.—The convention presents the broad policies of the organization and its three-tiered structure. It creates an assembly of the full membership of Inmarsat. Each member nation has one vote in the assembly.

A council represents the major investors but also has four members drawn from the signatories at large without respect to investment. It is the responsibility of the council to provide the Inmarsat space segment and to set standards for land and ship terminals. As of 1981, the council has 24 members.

A directorate, headed by a director general, will implement the council's actions.

b. Voting and representation.—The operating agreement specifies an initial $200-million capitalization for Inmarsat. Investment, or ownership, will be based on a nation's utilization of the space segment. In turn, voting on the Inmarsat council will be weighed according to ownership.

Initial investment in Inmarsat was negotiated according to anticipated utilization of the space segment by various nations. Later calculations will be based upon actual use.

Utilization will be calculated in two parts: (1) ship-to-satellite and satellite-to-ship, to be credited to the nation under whose authority the ship is operating; and (2) shore-to-satellite and satellite-to-shore, which would be credited to the nation in whose territory the traffic originates or terminates.

---

[55] "U.S., Soviet Differences Delay Inmarsat", Aviation Week and Space Technology, Mar. 8, 1976.

Any nation whose ownership exceeds 25 percent will be required to offer the ownership shares in excees of 25 percent to other member nations. If no country accepts the offer, the nations can retain the ownership, and voting strength, in excess of 25 percent.

The current Inmarsat member nations, and their percentage investment shares, are set forth in table 3-1. The five major investors, in order, are the United States, the U.S.S.R., the United Kingdom, Norway, and Japan.

TABLE 3-1.—*INMARSAT Members*

Country	Investment Share %
United States	23.36370
U.S.S.R.*	14.09217
United Kingdom	9.89134
Norway	7.87821
Japan	6.99915
Italy	3.35524
France	2.88553
Germany, Federal Republic of	2.88553
Greece	2.88553
Netherlands	2.88553
Canada	2.61717
Kuwait	2.01315
Spain	2.01315
Sweden	1.87898
Australia	1.67770
Brazil	1.67770
Denmark	1.67770
India	1.67770
Poland	1.67770
Singapore	1.67770
China, People's Republic of	1.23666
Argentina	0.60395
Belgium	0.60395
Finland	0.60395
New Zealand	0.36277
Bulgaria	0.27204
Portugal	0.20610
Algeria	0.05000
Chile	0.05000
Egypt	0.05000
Iraq	0.05000
Liberia	0.05000
Oman	0.05000
Philippines	0.05000
Sri Lanka	0.05000
	100.00000

---

* Includes the initial investment shares of Byelorussian S.S.R. and Ukranian S.S.R.

Source: COMSAT

4. *Proposed interim arrangements*

a. Joint venture.—A number of nations were concerned that there would be a gap in maritime satellite communications services between the time that Marisat capabilities diminished and the time that Inmarsat could have an operational system going. A Joint Venture group began meeting regularly in November 1977 to plan for an interim system to ensure continuity of maritime satellite services while paving the way for the new international system. This pre-Inmarsat organization was called the Joint Venture for a Global Maritime System. It was set up by prospective Inmarsat participants to start satellite procurements in time to succeed Marisat at the end of its anticipated 5-year lifetime in the early 1980s. The Joint Venture was spearheaded by European telecommunication authorities.

b. Comsat.—Comsat was looking at a follow-on system to Marisat during this time period and had attended some of the Joint Venture meetings. However, Comsat's preference for a follow-on system was to put civilian maritime communications packages on the U.S. Navy's proposed Leasat. (Comsat prepared a proposal for the Navy for a hybrid Leasat which would have capacity and power in excess of Navy requirements and which thus could be used for civilian maritime communications.)

This was not a popular idea with most of the nations involved in the pre-Inmarsat arrangements; most parties were concerned about the military/civilian link. Another objection was that Leasat was a United States, not a multinational program. Comsat was not awarded the Leasat contract by the Navy, so the question became moot.

c. Pre-Inmarsat agreement.—Comsat was still exploring possible follow-on systems to Marisat when the joint venture nations drafted an agreement to establish a pre-Inmarsat system based on either three Intelsat 5 packages plus 3 European Space Agency [ESA] Marec's or 4 Marec's. This agreement was drafted at the fall of 1978 meeting in Bergen, Norway, at which the United States did not have a representative. Though the joint venture nations did endorse a resolution in March 1979 for an international system based on the Marec's and Intelsat spacecraft (with the United States and Canada abstaining), the venture lacked the ability to act because the agreements to bring the joint venture into existence were never signed. With the entry into force of the Inmarsat Convention in July 1979, the need for the joint venture was obviated and planning began for the operational Inmarsat system.

5. *Establishment of operational Inmarsat*

Inmarsat has set up its headquarters in London, and has chosen a Norwegian Director-General. Commercial service began on February 1, 1982, at which time Inmarsat took over the customer base of Marisat. By August 1982, there were over 1,350 terminals in operation.[56] By 1985, there are anticipated to be 2,000 users under Inmarsat and 3,800 by 1988.[57] Thus, establishment of Inmarsat will mean continued expansion and improvement in communications with ships at sea. The total cost of Inmarsat operations is anticipated to be about $180 million for the first 7 years.[58] At this time Inmarsat has 37 members who will share this cost.

---

[56] Inmarsat New Release. Aug. 9, 1982.

[57] "Marifacts. The Changing of the Guard, May 1981," p. 5. Published by Comsat.

a. Space segment.—Decisions on the space segment for the period 1982–1988 were made at the Inmarsat Council meeting in London in November 1980. The council authorized a three part space and signed three agreements with suppliers for the following maritime communications capability:

(1) Two dedicated European Space Agency [ESA] Marec's spacecraft leased for 5 years each with 2 years extension possible, for launch via Ariane (the European space launch vehicle) in late 1981 and early 1982 to cover the Atlantic and Pacific;

(2) Maritime communications packages on three Intelsat V's with options on a fourth Intelsat V, leased for 7 years, first launch for late 1981 to the Indian Ocean, second to Atlantic, third to the Indian Ocean as a spare, and the fourth, to the Pacific; and

(3) Two years of service on Marisat's Pacific satellite to begin in February 1982 with an option on the Indian Ocean Marisat.

The Council also selected Comsat and Kokusai Denshin Denwa [KDD], Japan, to carry out the Inmarsat coordination services for 7 years.

Discussions on procuring additional services (beyond this first set for 1982–1988) will be made toward the end of 1983 or early in 1984.

As an interim service until the Inmarsat is fully operational, Inmarsat is leasing capacity from all three Marisat's. This decision was reached at the June/July 1981 Inmarsat Council meeting in London. At its July 1982 Council meeting in Norway, Inmarsat agreed to exercise its option to extend its leases on Comsat's Marisat satellites to ensure continuity of service.

b. User segment.—One of the requirements of the Inmarsat maritime communications system was that it be compatible with Marisat and thus achieve continuity with the Marisat system. Thus, a key provision in selection of the space segment was that the Marisat user terminals would be compatible with it. All user terminals now in place will be able to transition to Inmarsat. Though there were very few manufacturers of shipboard terminals when Marisat started, there are now about 40 companies involved in, or interested in, entering this market. As in Marisat, all user terminals will be owned and operated, or leased and operated, by the user.

c. Ground segment.—The major difference between the ground segment for Inmarsat and the ground segment of Marisat is that telecommunications can be routed via any of several earth stations in an ocean region, rather than just one under the Marisat system. The ground network will include all of Intelsat's ground network plus the three Marsat stations in Southbury, Conn., Santa Paula, Calif.; and Yamaguchi, Japan. Additional earth stations are expected to be operational in 1982, 1983, and 1984 (see table 3–2).

---

[58] Flight International. Mar. 28, 1981, p. 911.

TABLE 3-2.—INMARSAT SHORE STATIONS, EXISTING AND PLANNED

SHORE STATION	OPERATION DATE	OCEAN REGION
Argentina, Mar Del Plata	1983	Atlantic
Brazil, Tangua	1983	Atlantic
Egypt, Maadi	1983	Pending
France, Pleumeur Bodou	1982	Atlantic
Greece, Thermopylae	1982-83	Atlantic
Hong Kong	1983	Pacific
Italy, Fucino	1982	Atlantic
Japan, Ibaraki	1982	Pacific
Japan, Yamaguchi	Operating	Indian
Kuwait, Umm-Al-Aish	1982	Atlantic
Norway, Eik--with Denmark, Finland & Sweden	1982	Indian or Atlantic
Oman, Muscat-Wattaya	1983	Atlantic and Indian
People's Republic of China, Beijing	Pending	Indian and Pacific
Singapore	1982	Pacific
United Kingdom, Goonhilly	1982	Atlantic
USA, California	Operating	Pacific
USA, Connecticut	Operating	Atlantic
USSR, Nakhdoka	1983	Pacific
USSR, Odessa	1982	Atlantic

For each of the three major ocean areas--Atlantic, Pacific, and Indian--a Network Coordination Station (NCS) will govern the accessing of the satellite serving that ocean. All shore stations serving that ocean area will be linked with an NCS. The stations also will be connected to a variety of telecommunications carriers' networks for distribution of traffic between marine units and points on shore.

Source: Data for this list were provided by the INMARSAT Directorate's Office and is current as of April 1981. Marifacts, May 1981, v. 7, no. 1, p. 7. Published by COMSAT.

All shore stations will be owned and operated by Inmarsat signatories. If all the expected earth stations materialize, there will be eleven for the Atlantic region, six for the Pacific, and four for the Indian Ocean region.

There will be a Network Coordination Station [NCS] for each of the three major ocean areas. Each NCS will govern accessing of the satellite serving that ocean area. For the Atlantic area, the NCS will be Southbury, Conn.; for the Pacific it will be Ibaraki, Japan; and for the Indian Ocean it will be Yamaguchi, Japan. Each coast earth station will be linked to the appropriate NCS and each will be linked to a number of telecommunications carriers' networks for distribution of communications traffic.

An overall Operations Control Center will be set up in London to made sure operations are smooth between the coast Earth stations, the NCS stations, and the Satellite Technical Control Centers. These latter will be operated by the three space segment suppliers and will be operational in 1982.

d. Services.—The services to be provided by Inmarsat will approximate those of Marisat. There will be available: (1) automatic (dial) telephone service; (2) voice grade data service (including facsimile); (3) telex/TWX. Another service which may be included but is not certain at this time is a wide-band data service at 56 kilobits per second for ship-to-shore data traffic. This service would enable rapid transmission to shore bases of computer data which is not now always economically feasible. An example would be seismic survey results.

6. U.S. involvement in Inmarsat

a. Need for legislation.—After the Inmarsat agreements were opened for signature, the U.S. Congress considered the issue of whether the United States should participate in the organization and, if so, what type of institution would be the most appropriate vehicle to represent U.S. interests. Legislation was seen as necessary by the Congress and by the administration to (1) provide authority for the U.S. Government to sign the Inmarsat Convention; (2) to designate an entity to be the sole U.S. participant in Inmarsat and to sign the operating agreement; (3) to insure full and fair competition in the provision of service to users; while retaining incentives for private capital investment; and (4) to provide for appropriate governmental oversight.

Several bills regarding U.S. participation in Inmarsat were introduced in late 1977 and early 1978.[59] Although the bills differed in their approach to the U.S. designated entity, they all did state that the United States should participate in an international maritime telecommunications organization in order to insure meaningful participation in a follow-on system to Marisat. Three different congressional committees held hearings on the proposed legislation in the spring of 1978.[60] At the hearings, three alternatives for partici-

---

[59] 95th Congress, H.R. 11209, S. 2211, and H.R. 9647.

[60] U.S. Congress. House. Committee on Interstate and Foreign Commerce. International Maritime Satellite Act. Hearing before Subcommittee on Communications, 95th Congress, 2d Session, April 4, 1978, on H.R. 11209, 130 p.

Continued

pation in Inmarsat were discussed: a new private corporation owned by the common carriers, a consortium of U.S. carriers, or Comsat.

b. Administration views on participation in Inmarsat.—At the hearings the administration advocated the creation of a new private corporation to be owned initially by certified common carriers in proportions to be determined by the Federal Communications Commission. The details of the intercorporate and othe relationships between the entity and its constituent owners would be left to the Federal Communications Commission.

The administration testified that consideration was given to Comsat as the U.S. designated entity.[61] However, the administration believed that potential conflicts of interest existed in such a case. Since Comsat is the sole U.S. representative to Intelsat, and since Comsat owns the largest single share of Intelsat, it is in a unique position to influence decisions made by that organization. According to the administration, if Comsat was designated the sole U.S. representative to Inmarsat, where the U.S. designee would also own the largest simgle share, it would be in a position to exert considerable influence over that organization. The administration feared that a conflict would arise should the interests of these two organizations not be totally consistent, In addition, the administration stated that designating Comsat as the chosen instrument in Inmarsat would, by enlarging Comsat's monoploy role in international space communications, encourage a monopolistic solution to future international commercial space communications ventures. This position was supported by the international record carriers.

c. Congressional views.—A key factor during congressional consideration was that international maritime satellite facilities, because of the very high initial investment and operating costs and a potentially limited maritime market, would be provided by a single, integrated system, with little chance for duplicative competitive systems to exist. The U.S. operating entity would be the sole supplier of U.S. segment capacity obtained from the system. Thus, whether it was a multi-carrier-owned corporation or Comsat, that entity would be a monoploy, and, as such, would be subject to Federal Communications Commission authority. The rates would be based on costs determined by the entity's investment plus a fair rate of return, also to be set by the Commission.

Thus, the issue was seen not as one of avoiding the creation of a monopoly, but rather how to insure that the integrated satellite system would be operated effectively and efficiently, while preserving the competitive environment for the pickup and delivery of maritime communications services.[62] Congressional concern was

---

U.S. Congress. House. Committee on Merchant Marine and Fisheries. Merchant Marine Miscellaneous—Part 2. Hearings before Subcommittee on Merchant Marine, 95th Congress, 2d Session, March 21, 1978, on H.R.11209, p. 167-272.

U.S. Congress. Senate. Committee on Commerce, Science, and Transportation, International Maritime Satellite Telecommunications, Hearings before Subcommittee on Communications, May 8, 1978, on S. 2211 and H.R. 11209, 95th Congress, 2d Session, 156 p.

[61] U.S. Senate. Committee on Commerce, Science, and Transportation. International Maritime Satellite Telecommunications. Hearings on S. 2211 and H.R. 11209, 95th Congress, 2d Session, May 8, 1978, p. 64.

[62] U.S. Congress. Senate. International Maritime Satellite Telecommunications Act, 95th Congress, 2d Session, S. Rept. 95-1036, July 25, 1978. Report to accompany H.R. 11209, p. 6.

that if a group of competing carries were allowed to own and control the satellite entity, there would be a possibility of collusion to divide the market even if ownership was offered to all interconnecting carriers. A potential for arbitrary market segmentation and joint marketing would have remained. In addition, cooperation in owning and operating the satellite segment could extend to rates and services offered the public. These were among the reasons that the Congress, during its consideration of the legislation relating to Inmarsat, decided that the U.S. designated entity should not own or be owned by any carrier which participates in the competitive pickup and delivery of maritime services within the United States.[63]

Regarding the structure of the U.S.-designated entity, the Congress decided that, within the context of an international organization which will require legal and financial responsibility, a corporation owned by carriers or a consortium of carriers would prove undesirable, and that a single management structure would be needed to represent U.S. interests effectively. The argument favoring the creation of a carrier-owned corporation or carrier consortium failed to describe the proposed decisionmaking process of such an entity. The FCC would be required to intervene on issues which the carriers might be incapable of resolving. Thus, the Commission would have been required to make business decisions that, according to congressional reports, would have been inappropriate for the regulatory process. The complications resulting from the disparate process likely to arise would be a major hindrance to the effective and efficient participation in Inmarsat by a multi-carrier-owned corporation or consortium.

Rather than expressing concern over Comsat's role in Intelsat as leading to a potential conflict of interest situation, the Congress decided that Comsat's experience in Intelsat would enable it to better minimize overhead costs than a multi-carrier-owned corporation or consortium.

For these reasons, in the legislation as reported in the House and Senate[64] Comsat was designated the sole supplier of U.S. space segment capacity obtained from Inmarsat. Left to be decided were the arrangements for making services available to tariffing domestic customers. The two options of Comsat's role were those of a carrier's carrier or a participating carrier.

Carrier's carrier.—Under this arrangement, the U.S. entity would provide satellite transmission capacity to the common carriers authorized to obtain such capacity and use it, together with other facilities, to provide an end-to-end service to the customer. As a carrier's carrier, the entity would file tariff schedules with the Commission showing the rates changed to the carriers. The carriers would file tariffs showing the rates paid by their customers for total, end-to-end service. These rates would incorporate the rates they paid to the carrier's carrier for the satellite segment capacity.

---

[63] Ibid; and U.S. Congress. House. Committee on Interstate and Foreign Commerce. International/Maritime Satellite Telecommunications Act, 95th Congress, 2d Session, H. Rept. 95-1134, pt. 1, May 11, 1978; and U.S. Congress. House Committee on Merchant Marine and Fisheries, International Maritime Satellite Telecommunications Act, 95th Congress, 2d Session, H. Rept. 95-1134, pt. II, May 11, 1978.

[64] H. Rept. 95-1134, Pt. I and II and S. Rept. 95-1036.

Comsat's role in Intelsat was previously that of a carrier's carrier. On August 5, 1982, the FCC authorized Comsat to provide service directly to end users. (See ch. 2, sec. III.)

Participating carrier.—As a participating carrier, the U.S. entity's function would be to receive and assemble maritime satellite traffic at the Earth stations and route outbound traffic over the satellite system to ship and other marine stations and inbound traffic to the appropriate carrier for terrestrial pickup and delivery to onshore points. The entity would not be limited to providing transmission capacity to authorized carriers, but would retain responsibility to the public for satellite services. In order for the customer to gain access to the satellite system, existing and future carriers would be authorized to connect their system to the satellite system at the Earth stations. The entity would file tariffs with the Commission reflecting the rates to the public for use of the total satellite system portion of the maritime satellite services, that is, Earth station to marine station and vice versa. The domestic and international carriers would provide customer access to the satellite system by interconnecting their onshore networks to the entity's Earth station facilities, and they would file tariffs showing the rates to customers for this service. Thus, the entity and the domestic and international carriers would participate in providing a through service to the customer.

The Congress perceived a number of advantages in the participating carrier arrangement.[65] First would be the elimination of the middlemen. The carriers authorized under a carrier's carrier arrangement to provide end-to-end maritime satellite services would be acting as middlemen and would incur administrative expenses in leasing transmission capacity from the entity, such as personnel, recordkeeping, and other overhead expenses customary for any business activity. Second, those carriers would also incur investment costs and maintenance expenses for test equipment and other facilities necessary to undertake overall operational responsibility for end-to-end maritime satellite service. Those functions would duplicate many of the functions performed by the U.S. entity.

Second, it was decided that the participating carrier method would provide for the most efficient use of the available capacity of the satellite. With the large volume of traffic in Comsat's arrangement in Intelsat, leased satellite capacity dedicated to the use of a carrier to use as it deems best, is a desirable mode of utilizing the space segment. However, with respect to Inmarsat, in which there would not be a great deal of traffic going to any one ship at sea, it might not be the most efficient use to have each carrier leasing a channel which would sit idle when there was no traffic. Under the participating carrier method, the communications companies would receive all of the traffic, transmit it to the satellite entity and the entity would collate it and transmit it in the most efficient manner via satellite. Thus, the participating carrier method was thought by the Congress to offer the potential or more effectively utilizing the capacity of the satellite and the protection against overcapitalization by having excess capacity which was dedicated but not used when not required.

---

[65] S. Rept. 95-1036, op. cit.

Earth station ownership.—During their consideration of the legislation, the House and Senate disagreed on ownership of the earth stations, that is, whether the stations should be owned only by the designated entity, Comsat, or whether they could be owned by other eligible entities such as common carriers and private communications systems. The Senate considered that a single entity operating the total maritime system would be most efficient and that multiple ownership would be more costly and would pose added regulatory burdens.[66] The House, on the other hand, believed that ownership of earth stations by other eligible entities should not be precluded. Though very few earth stations are required for present maritime communications, future growth in Inmarsat may necessitate greater number of less costly stations and there might be a role for other owners in addition to Comsat.[67]

d. Inmarsat legislation enacted.—The legislation, as finally agreed to by the Congress, and approved by the President, stated that (1) it was the policy of the United States to participate in Inmarsat; (2) that Comsat was designated the sole operating entity of the United States for participation in Inmarsat; (3) that any person or party may own and/or operate an earth terminal; (4) that Comsat would function as a participating, rather than a carrier's carrier; (5) that the U.S. President would have supervision over, and issue instructions to, Comsat in connection with the national interest and U.S. foreign policy; and (6) that the FCC is authorized to oversee Comsat with respect to regulatory matters within its jurisdiction and the Commerce Department to oversee Comsat with respect to matters under its jurisdiction.[68] Further, the measure called for three studies to ensure smooth operation of the U.S. participation in Inmarsat through Comsat. One study was to be on the corporate structure and operating activities of Comsat to see if any changes were necessary to meet the requirements of the legislation. A second study was on public maritime coast station services to see whether the rules and regulations needed to be altered to implement the measure. A third study was on government radio navigation systems to reduce proliferation and overlap of such systems.

With the signing of the legislation, the way was clear for Comsat to commence its activities relative to Inmarsat. The U.S. Government signed the Inmarsat Convention in February 1979 and Comsat signed the operating agreement in January 1979. As the U.S. designated entity, Comsat has a financial interest in Inmarsat facilities (including the space segment) and will share in the organization's revenues and expenses. As a participating carrier, Comsat is able to supply services directly to users.

e. Federal Communications Commission action.—On August 17, 1982, the Federal Communications Commission [FCC] released its Opinion and Order (FCC 82-375) implementing the requirements of the International Maritime Satellite Telecommunications Act. The FCC adopted a policy which will permit persons other than Comsat to own future shore stations which access Inmarsat, if it is shown to be in the public interest. The FCC also concluded that Comsat's proposal to combine the net expenses of its Inmarsat activities with its Intelsat revenue requirements for the purpose of setting rates is not in the public interest and should not be approved.

---

[66] U.S. Congress. Senate. Rept. 95-1036. International Maritime Satellite Telecommunications Act, July 25, 1978, p. 12, op. cit.

[67] U.S. Congress. House. Rept. 95-1134, pt. I, International Maritime Satellites. p. 12.

[68] Public Law 95-564, amendment to the Communications Satellite Act of 1962, to provide for the establishment, ownership, operation, and governmental oversight and regulation of international maritime satellite telecommunication services. Signed Nov. 1, 1978, 92 Stat. 2394.

7. Next generation maritime satellites

The first generation Inmarsat satellite system is planned for operations into 1988. In order to assure continuity of service, planning for a follow-on system will have to begin in 1982. Inmarsat's technical committee will begin to look at traffic projections and technical requirements for a follow-on system at that time.

VI. PUBLIC SERVICE COMMUNICATIONS SATELLITE PROGRAMS

A. INTRODUCTION

Commercial satellite communication systems provide a fast and reliable worldwide communication link. Most present-day satellite communication is handled by common carriers who integrate their space communications into their existing ground networks. The satellite provides a long-distance link, with local and regional service handled by ground link. Since a heavier payload necessarily increases the cost of the launch, it is to the economic advantage of the carriers to use a simple, relatively light-weight satellite, and place the heavy technical burden on a few large and expensive regional ground stations.

Such a communication system serves efficiently the easily accessible, heavily populated areas of the world. There are, however, many remote, sparsely populated areas for whom terrestrial communication links are physically impossible or economically prohibitive.[69] A versatile, relatively inexpensive communication system is useful for such regions.

In addition to the advantages remote communities gain from satellite communications services, there is also a large potential market for satellite delivery of social service broadcast in such areas as education, medicine, counseling, and public safety.

One system which responds to these needs provides communications between any two points in a given area with both fixed and moving terminals on a continuous 24-hour basis. The communications include two-way video service between the stationary and two-way audio service between the mobile terminals. The system includes small, affordable stationary terminals to serve health, education, and other public services provided by Federal, State, and local government agencies as well as other organizations; portable terminals for emergencies and disasters; and mobile terminals to serve moving vehicles for emergency medicine, safety, and law enforcement needs.

---

[69] In the United States alone it has been estimated that to reach the last 10 percent of the people would cost as much as reaching the first 90 percent. Remarks of Caspar Weinberger, a news conference on applications technology—6, May 22, 1974, p. 6.

Such a system requires transferring the burden of the satellite communications network from the Earth station to the satellite. This is accomplished by increasing the satellite transmission power as well as its ability to focus this power. Thus, unlike conventional satellites which transmit moderately powerful broadcasts over large geographical areas, the public service communications satellites deliver high power transmissions to relatively limited areas. The resultant decrease in the cost and the complexity of the receiver stations places satellite broadcasting into the budgetary grasp of the small, independent user and opens the door to a wide variety of social service broadcasts by satellite.

The potential uses are numerous. Medical students in dispersed geographical locations can receive televised instruction from a major medical center. Consultations can be conducted and data such as EKGs, medical histories, and laboratory reports for diagnostic purposes can be exchanged among physicians at distant hospitals.

Lectures as well as audio-visual materials originating at one learning center can be made available to many geographically dispersed schools, libraries, hospitals, industrial plants, and offices. Schools which are geographically separated but educationally related can, through satellite interconnection, become functional units in special systems, enabling them to share resources and instructional materials designed to meet their common needs.

Libraries and computerized data bases across a nation can be linked for instant access and transfer of information. State and interstate communications systems for administration, health, law enforcement, highways, conservation, and public safety can be coordinated. Video teleconferencing can save business companies travel expenses while affording access to scattered offices.

These possibilities led to considerable experimentation on the NASA Applications Technology Satellite [ATS] series as well as on the U.S./Canadian Communications Technology Satellite [CTS]. In particular, the public service potential of satellites inspired the development of the ATS–6. ATS–6 was a powerful and complex spacecraft; its related Earth stations were simple, cheap, and reliable. It was designed to explore and demonstrate the ways communications satellites could be used to meet a wide range of public needs. Following the retirement of both ATS–6 and CTS and a U.S. policy decision to transition public service users from NASA experimental satellites to commercial satellites, nonprofit institutions have begun to serve as a focal point for aggregation of public service users to effectively utilize commercial satellites to meet public service needs. The section below outlines some of the major programs and organizations concerned with U.S. public service satellite communication programs and activities.

B. ATS–1 AND ATS–3

Launched in 1966 and 1967, respectively, ATS–1 and ATS–3 (Applications Technology Satellite) are continuing to support experimentation and utilization for public service needs far beyond their planned lifetime. At an annual cost to NASA of about $500,000 to $600,000 NASA operates the spacecraft, provides operations management, provides technical consultation, and supports demonstrations. The experimenters secure their own funding for conduct of the experiment, data gathering and analysis, preparation of their final report, and information dissemination. Experimenters also secure their own Earth terminals. There is no money exchanged between NASA and the experimenters.

1. (ATS-1) Peacesat

In 1971 the University of Hawaii initiated the Pan Pacific Educational and Communication Experiments by Satellite [Peacesat]. The program uses the discarded ATS-1 satellite stationed above the Pacific, midway between Hawaii amd Samoa, and ground equipment costing a few thousand dollars, to form a communications network linking schools, universities, and health care facilities.

Peacesat provided the world with the first satellite library network, the first satellite education network, and the first regional satellite network. It has been the vehicle for a communications link for educational, scientific, and cultural exchanges between Australia, New Zealand, Papua, New Guinea, Fiji, Tonga, the Solomon Islands, the Gilbert Islands, Samoa, and the United States. Although teleprinter and facsimile are occasionally used, the majority of exchanges are voice only.[70, 71]

As of the writing, ATS-1 is still functioning, though there has been some degradation of capability.

2. ATS-3

In the United States, ATS-3 is supporting emergency medical experiments conducted with the Southern Regional Medical Consortium and involving three States (Alabama, Louisiana, and Mississippi). These experiments are being conducted to ascertain the value and cost effectiveness of mobile communications via satellite for emergency notification, vehicle dispatch, and two-way voice biomedical telemetry between paramedics and hospital physicians. ATS-3 communications to rural, wilderness, and offshore recreational and oil rig applications are emphasized. The major activities being tested through these experiments are responses to trauma and cardiac cases among oil rig workers in the Gulf of Mexico and land transfers of critically ill persons who are as far as 150 miles from specialized medical treatment.

C. APPLICATIONS TECHNOLOGY SATELLITE—6 [ATS-6]

1. Introduction

When the Applications Technology Satellite—6 [ATS-6] was launched into geosynchronous orbit on May 30, 1974, it was the most powerful communications satellite ever developed.[72] ATS-6 was the first spacecraft with sufficient transmitting power to broadcast directly to small and simple ground receiving units in

---

[70] Christine Negus. "Satellite Link Brings People of Pacific Closer—Expansion of the Unique PEACESAT Project Planned," Dominion (New Zealand), Jan. 14, 1976.

[71] Michael Balderson. "Satellite Communications for Education in the South Pacific," Educational Technology, April 1979: 26-30.

[72] It was superseded by the more powerful Canadian Technology Satellite [CTS].

remote regions covering large geographical areas. ATS-6 served an international community as a special broadcasting station in space.

For the first year of operation ATS-6 was positioned at 94 degrees west longitude over the Equator. From its station over the Galapagos Islands, the spacecraft was used primarily for health care and educational experiments in the Rocky Mountain region, the Appalachian States, and the States of Washington and Alaska.

Approximately 1 year after launch, ATS-6 was moved eastward to a station over the eastern edge of Lake Victoria in Kenya, East Africa. From this position the spacecraft was "visible" to the subcontinent of India. Then began a year-long cooperative experiment with the Indian Space Research Organization [ISRO] to evaluate the role of television by satellite in promoting rural development.

After the Indian experiment, NASA and the Agency for International Development [AID] embarked on a joint venture to use ATS-6 to demonstrate to people in 27 developing nations how space technology could improve their ways of life.

In July 1979 all experimentation with ATS-6 terminated. By that time three of the satellite's four station-keeping control jets failed and the lifetime of its fourth became questionable. To prevent possible interference with, or hazard to, present and future spacecraft in the same orbital region, ATS-6 was moved to a lower orbit. The satellite had outlived its original 2-year design lifetime by 3 years.

2. Technology

The ATS-6 spacecraft consisted essentially of an Earth Viewing Module [EVM] connected to a deployable reflector antenna that measured 9 meters (30 feet) in diameter when deployed. Spacecraft control, communications, and experiment systems were located in the EVM. Electrical power was supplied by two semicylindrical solar panels on arms that extended over and beyond the antenna.

The spacecraft's most critical elements were the deployable antenna and the communications transponder. Through these two systems, ground controllers relayed high-quality color television and other communications signals on multiple frequencies at high transmitter power levels and high-effective-radiated power levels to simple land, sea, and air receivers located over a large geographical area. This technology enabled scientists to conduct experiments in broadcasting health and education television programs to small, low-cost ground receiving units in remote regions; aeronautical and maritime communications, position-location, and traffic-control techniques; and spacecraft tracking and data relay.

3. SITE—Joint United States-India Experiment in Educational Broadcasting

During the Satellite Instructional Television Experiment [SITE], ATS-6 was moved eastward to a station over the eastern edge of Lake Victoria in Kenya, East Africa (1975).

From this position the spacecraft was "visible" to the subcontinent of India and was used in a year-long cooperative experiment with the Indian Space Research Organization [ISRO] to evaluate the role of television by satellite in promoting rural development.

a. The program.—During SITE, special programs developed in India were broadcast daily from a ground station near Ahmedabad, India, to the ATS–6 satellite. Serving as a powerful rebroadcasting station in space, the satellite relayed the institutional television programs directly to nearly 2,400 remote villages which had never before received television signals. These villages were equipped with small ground terminals, consisting of conventional television receivers augmented with small electronic components and inexpensive mesh antennas, all of which were built in India. Approximate cost of these simple units was $600 per unit.

Another 2,600 of the small ground terminals, located near conventional television transmitting stations, received the same ATS–6 instructional material and rebroadcasted it to numerous cities and nearby villages.

In all, an estimated 5 million people in six different village "cluster" areas throughout India viewed more than 1,200 hours of diversified programing dealing with basic subjects in agriculture, health, hygiene, family planning, national integration, science for youth, and teacher education.

NASA responsibilities for this experiment were to provide operating time on the ATS–6 communications transponder and to position and point the spacecraft from the ATS–6 mobile ground station located near Madrid, Spain. All other aspects of the experiment, including the design, development and manufacture of the ground transmitting and receiving stations and all programing, were the responsibility of the Government of India. The Indian Space Research Organization [ISRO] procured the hardware while All Indian Radio [AIR], had the prime responsibility for developing the programing in collaboration with ISRO.

b. The results.—Indian reaction to the ATS–6 SITE experiment was generally positive. Among the more immediately visible results of the broadcasts which were cited by project evaluators were improved school attendance, increased concern for proper nutrition, and an awareness of sanitation and personal hygiene as methods of disease prevention. One of the unanticipated benefits of the program was the electrification of numerous villages, a prerequisite for television reception.[73] Praise for the intangible benefits of the SITE project was perhaps best summarized in a report to the United Nations Committee on the Peaceful Uses of Outer Space:

> SITE can be considered a pace-setter and fore-runner of satellite television systems particularly of those meant for development. It is an example of technological and psychological emancipation of the developing world.
>
> Its most important element was the commitment and dedication of all people and organizations involved in the one overriding goal of rural development in India. From this follows the crucial role of motivation and cooperation for the success of complex and challenging tasks.[74]

A detailed document entitled "A Case Study of India's Satellite Instructional Television Project [SITE]," January 1977, prepared by Dr. Clifford Block, Dr. Dennis Foote, and Dr. John Mayo at the Agency for International Development [AID], Department of State, examined and evaluated the SITE experiment in more specific terms: technical aspects, project management, Indian location, programing, and indirect benefits. Several of the study's conclusions pointed to reasons for the success of the program and are summarized below.

---

[73] Report on the SITE Winter School, U.N. Committee on the Peaceful Uses of Outer Space, U.N. document No. A/AC.105/177, Dec. 1, 1976, p. 13.

[74] Ibid.

Technical aspects.—The AID report cited the SITE project as a demonstration of the successful large-scale use of sophisticated space technology in a developing country. SITE proved that video signals from a satellite can be reliably received in remote villages. The quality of picture and voice was excellent and the community reception systems experienced a 90-percent performance reliability. The AID report attributed this technical success to detailed planning, intensive maintenance, rapid adaptability to technical adversity, and an investment in a large network of repair technicians supported by a good supply of spare parts and flexible procedures.

Project management and institutional framework.—Success of the SITE project was also achieved by institutional flexibility, a firm commitment to the social goals of the experiment, and the maximum involvement of State and local governments.

In the AID report the institutional framework of the SITE experiment was given much credit for the general success of the project. The Indian Space Research Organization [ISRO], the managing agency, had entire control of technical operation, thus eliminating delays resulting from interagency coordination and maximizing institutional flexibility. In addition, the SITE experiment was given first priority within ISRO, insuring a single-mindedness of purpose in the agency which might not have been possible if the project had been assigned to an operational organization, such as the Ministry of Education, with many large programs to administer.

The report also asserted that the lack of a formal, detailed proposal as well as the research and development orientation of ISRO permitted flexibility of response to needs as they arose. Thus, it was possible to experiment with various potential solutions to problems until a successful approach was discovered.

Another reason given for the success of the program was the primacy of social goals throughout the experiment. Technical convenience was not permitted to overrule the commitment to the social goals of the project. An example illustrative of this steadfast commitment occurred when SITE planners discovered that electricity was not available in 80 percent of the proposed locations for the receiver sets. Rather than suggesting the relocation of the receivers in less primitive locations, they instead arranged for State governments to electrify the buildings.

Maximum involvement of State and local governments in the project was encouraged. This participation allowed ISRO to tap resources that would have been difficult for SITE officials to assemble, and to utilize local infrastructure for a portion of the field activities.

The Indian Context.—The AID report cited several advantages of the location of the SITE project in India: large pools of trained manpower in several essential fields, sustained political commitment from the highest levels of government, adequate funding, and strong existing institutions with clear institutional responsibilities. The report also stated that India's reliance on indigenous technical expertise resulted in the design of equipment that was appropriate to the rural environment and that could be produced in India.

The National Aeronautics and Space Act of 1958 mandates that the United States exploit space "for the benefit of all mankind." The apparent success of the SITE experiment suggests that this type of demonstration project may be a useful means of sharing the benefits of space technology with the lesser developed nations.

4. *AIDSAT—joint AID/NASA satellite communications demonstration project*

During its return voyage to the United States after the SITE project, ATS-6 was used to demonstrate how the application of space communications, remote sensing, and high resolution aerial photography can aid in food production, health and nutrition and land management. For these demonstrations, ATS-6 transmitted audio or audiovisual presentations in black and white or color to special ground receivers. The three month (August 1-October 30, 1976) project was a joint undertaking by the Agency for International Development [AID] and NASA.

The first half of the Aidsat project included demonstrations in Southeast and South Asia, the Middle East, and in East and North Africa. The second part of the program involved nations in West Africa, South and Central America and the Caribbean.

NASA technicians set up one transmitter-receiver unit in the capital of each participating nation and up to four receiver units in other cities and towns in the host country. Following the demonstration, the equipment was transported to the next participating country.

Programs included both filmed and live portions. The filmed portion consisted of a bicentennial greeting by President Ford, followed by three films produced for Aidsat by NASA. The first film, "If One Today, Two Tomorrow" concerns communications technology. "Images of Life" deals with remote sensing satellite capabilities and illustrates how Landsat imagery is used to facilitate range management in Africa's Sahel, to locate pure water in Kenya, to inventory forests in Thailand, to identify new land formation in Bangladesh, to locate iron ore deposits in Egypt, and to better plan highway routes in Iran and Bolivia. How aerial photography can be used in disaster relief, disaster assessment, and prediction of certain kinds of catastrophes such as earthquakes, volcanic eruptions and severe storms is the subject of the final film "Survival".

The live segment of the demonstration consisted of two 30-minute programs. the first, originating in the host country, featured ministers and officials outlining current technological challenges facing their nation and efforts to meet these challenges.

The second portion was a two-way television question-and-answer session between a panel of senior government officials in each host country and selected experts in Washington. Questions, posed by the host country and panelists, were generated by technical subjects in the film as they applied to each country. Panel members were selected from concerned areas of government, such as communications, education, health, forestry, planning, agriculture, hydrology, and geology.

Participants in the program included eight presidents, three prime ministers, a king and a sultan, as well as many top-ranking ministers and businessmen in the host countries. Although the project was directed toward high level decision and policymakers, millions of viewers watched the programs by direct or delayed tape broadcasts over national television networks. In many instances, demonstration broadcasts were the first ever received in color in the host country. In some cases the demonstration presented the first opportunity for a nationwide television connection in the participating country.

Those nations which participated in the project were: Thailand, Bangladesh, Pakistan, United Arab Emirates, Oman, Jordan, Yemen, Kenya, Libya, Sudan, Morocco, Mali, Cameroon, Central African Republic, Ivory Coast, Upper Volta, Mano River Union (Sierra Leone and Liberia), Peru, Argentina, Bolivia, Uruguay, Ecuador, Surinam, Costa Rica, Jamaica, and Haiti.

AID provided $3 million to fund the project. NASA and AID formed a joint working group to determine how experience from the Aidsat project can be applied to future international collaborative programs.

5. ATS-6 mission costs

The cost to NASA for the ATS-6 mission is approximately $180 million for the spacecraft, including development and testing and backup hardware, and $25 million for the launch vehicle and services.

D. Communications Technology Satellite [CTS]

1. Introduction

The Canadian Communications Technology Satellite [CTS] was a joint United States-Canadian effort. Launched into a geosynchronous orbit on January 17, 1976, CTS was stationed over the Equator at an altitude of approximately 36,000 kilometers (22,300 miles) at 116 degrees west longitude, just west of South America. Its position allowed both United States and Canadian experimenters to use the satellite.

Based on the technology developed for the Applications Technology Satellite-6 [ATS-6], the CTS was designed for high powered transmissions of color television and voice communications to small, user-operated ground terminals.[75] The transmitting power levels were 10-20 times higher than commercial communications satellites at that time, which were designed to operate with large, complex ground terminals. The high satellite power of CTS allowed experimenters to conduct a multitude of communication service demonstrations with a modest investment in ground receiving equipment. This communications capability was particularly attractive in remote areas of the United States and Canada where terrestrial communications are not highly developed. Such techniques also have considerable potential for most developing countries.

---

[75] CTS was designed to demonstrate interactive communications compared to the more broadcast-oriented goals of ATS-6.

The objective of the CTS program was to advance the technology of both spacecraft-mounted and related ground-based components and systems applicable to high-radiated-radiofrequency power satellites. To achieve this objective, the spacecraft demonstrated new technology applications and conducted experiments on components and systems that would be applicable to future commercial communications satellites. The program also included communications experiments with user agencies, universities and industrial groups in the United States and Canada.

2. *Technology*

Communications satellite systems at that time operated in a 4 to 6 GHz frequency band shared with other types of systems on the ground. Limitations on satellite power levels were required to prevent interference. This was a major factor in dictating the use of large and expensive ground antennas.

Better ways to expand television, voice and data transmission to even the most remote locations were needed. One solution was the use of new, more powerful satellites operating at much higher frequencies, with smaller, less expensive, even portable ground stations.

The CTS operated in a new frequency band allocated for broadcast satellites, 12 GHz. It was therefore able to operate at higher power levels (200 watts) without interfering with other communications satellites. Signal reception was possible with a simple, low cost receiver.[76]

The problem of building a more powerful satellite while staying within the weight limitations imposed by the capabilities of available launch vehicles led to the development of a radically different satellite. The design of the CTS centered around three major advanced technical subsystems:

1. A pair of lightweight, extendable arrays carrying enough solar cells to provide an initial power output greater than 1 kilowatt.
2. A traveling-wave-tube [TWT] amplifier of novel design, having an effeciency of 50 percent, at a power output of 200 watts.
3. A three-axis stabilization system, employing a fixed momentum wheel and hydrazine gas thrusters, to maintain antenna boresight point accuracy to within plus or minus .2 degrees in pitch and roll and plus or minus 1 degree in yaw.

Conventional U.S.-built communication satellites are stabilized by spinning. Because solar power cells are mounted on their outer circumference, roughly two-thirds of the cells are in darkness at any one time. Such a one-third-efficiency power source was not sufficient for the CTS design.

To provide the necessary power, a pair of arrays, each approximately three times as long as the diameter of the spacecraft body, were developed. A sensor mounted on each extended sail controlled a drive mechanism to enable the sail to track the Sun.

The primary function of the CTS three-axis stabilization system, the first in a communications satellite with flexible arrays, was to keep the satellite antennas pointing accurately toward the center of selected target areas on the surface of the Earth, while the solar sails always faced the Sun.

---

[76] ATS-6 achieved its high power by use of a 9-meter (30 foot) reflector antenna; CTS by means of its very high-power (200 watts) transmitter. ATS-6's effective radiated power was 53 DBW (decibel watt); that of CTS was 59 DBW.

3. United States-Canadian cooperation

The CTS program began on April 20, 1971, when NASA and the Canadian Department of Communications [DOC] signed a memorandum of understanding in which they agreed to undertake, on a joint basis, the development and launching of an experimental satellite to extend communications technology to much higher power levels of transmission than had been previously used.

Under the agreement, the Canadians designed and built the spacecraft at the Communications Research Centre [CRC] near Ottawa. NASA provided the spacecraft's high efficiency 200-watt travelling wave tube for the transmitter, together with its power supply. Environmental test facilities at the Lewis Research Center in Cleveland, Ohio, and at the Goddard Space Flight Center in Greebelt, Md. were used to test the spacecraft. NASA also furnished the Delta model 2914 launch vehicle which placed the satellite in its geo-stationary orbit.

The CTS mission was divided into the following phases: launch, transfer orbit, apogee injection (motor firing), spacecraft drift to station, three-axis attitude acquisition and in-orbit operation. The first four phases were the responsibility of NASA, while the Canadians [CRC] were responsible for the three-axis attitude acquisition and in-orbit operation.

The combined United States and Canadian technology and communications experiment activities were planned and coordinated through a Canadian [DOC]-NASA joint working group.

4. Experiments

The policy of both NASA and DOC encouraged wide participation from a variety of organizations such as State (or Provincial) and local governments, universities, industry, and the scientific community. As a result, many sociological and technical experiments were performed that are expected ultimately to create markets for commercial services and space technology both in the United States and abroad.

Communications experiments carried out by a variety of groups in both the United States and Canada included those in technology, health care, community services, education, and special services. More specifically, among those experiments were the following:

Education

College curriculum sharing among universities.

Teacher upgrading by improvement of teaching skills and development of instructional units and making graduate education available to teachers.

Exchange of materials and teaching techniques between diverse areas of the country.

Investigation of telecommunications systems requiring only limited human support and providing data on career development, employment, job preparation and counseling.

Health care

Conducting biomedical and clinical experiments among 27 Veterans Administration Hospitals.

Demonstration of the feasibility of information exchange between research institutions and the medical community; evaluation of the broadband teleconference as a means of continuing education among health-care professionals.

Telemedicine between remote areas and urban health care centers.

Community and special services

Feasiblity of a satellite library information network to improve individual and organizational capabilities for assessing and disseminating information.

Substitution of video and audio teleconferencing for travel by a geographically dispersed industrial organization.

Demonstration of the suitability of transportable Earth terminals to relay communications to and from a disaster area.

Evaluation of low-cost receivers under field conditions.

In the United States, each experimenter was responsible for providing the necessary ground terminals. Except during preliminary checkout of the satellite's 200-watt traveling wave tube transmitter, each U.S. experimenter operated and maintained their ground terminal equipment.

Use of the spacecraft was evenly divided between United States and Canadian experimenters. The United States operated the spacecraft on Monday, Wednesday, and Friday, and Canada did so on Tuesday, Thursday, and Saturday. The two nations alternated operations on Sunday.[77]

5. Cost

The total cost of the program was about $82.5 million. The program cost to NASA was about $11.4 million with an additional $10.8 million for the launch vehicle. The cost to the Canadians of designing and building the satellite was $60.3 million.

6. Program termination

Public service user experiments on CTS were completed on June 30, 1979, and the satellite was retired in October 1979. During its 3½ year lifetime, more than 160 U.S. experiments were conducted on CTS, ranging from business teleconferences to emergency use during natural disasters. CTS demonstrated that more powerful satellites can bring low-cost television to remote areas anywhere on the Earth for a wide variety of public service uses.[78]

---

[77] "U.S./Canadian Satcom proves Effective with Small Antennas," Aviation Week and Space Technology, Dec. 13, 1976, p. 28.

[78] NASA press release 79-116. "U.S.-Canadian Satellite to Cease Communications Experiments." Sept. 13, 1979. p. 1.

E. U.S. POLICY FOR PUBLIC SERVICE COMMUNICATION PROGRAMS FOLLOWING ATS-6 AND CTS

1. Policy review

In 1973, a policy decision was made that advanced technology development for space communications would no longer be done by the Federal Government. This included research and development on public service communications technologies. The ATS-6 and the CTS programs discussed above had been initiated prior to that time and were not canceled. However, the were launched and supported by NASA through the 1970's. However, the vigorous communications programs started in the 1960's including the ATS series, were phased down. The expectation had been that the private sector would fund continued advanced communications research and development, including that for public service needs.

During the mid-1970's an extensive review of the Federal role in advanced communications research and development took place because it became clear that in the absence of significant Federal funding, the U.S. position in this area was eroding.[79] In addition to a prestigious National Academy of Sciences committee (known as the Davenport committee after its chairman Dr. Wilbur Davenport, Jr.) which reviewed the issue in 1976, the Office of Science and Technology Policy [OSTP] explored the Federal role in satellite communications research and development in general and in public service satellite communications in particular.

The Administration was interested in public service uses of satellite telecommunications and, as part of the Administration's review of U.S. space policy, the President's Policy Review Committee [Space] addressed the topic of public service satellites. The October 1979 Presidential Directive on the U.S. Civil Space Policy directed the National Telecommunications and Information Administration to begin activities in aggregation and possible development of domestic and international public satellite services. The press release on the directive stated that:[80]

> Some areas of communications services—such as educational and health services and basic communications services for remote areas—involve low-volume and intermittent use and have evidenced little interest from commerical satellite operators. The Department of Commerce's National Telecommunications and Information Administration (NTIA) will assist in market aggregation, technology transfer, and possible development of domestic and international public satellite services. This direction is intended to stimuate the aggregation of the public service market drawing on the technology that is already in existence. The Agency for International Development and Interior will work with NTIA in translating domestic experience in public service programs into potential programs for lesser-developed countries and the remote territories.

2. NTIA role

Pursuant to this directive, NTIA started a satellite applications program in cooperation with the Department of the Interior and the Agency for International Development. In 1980, NTIA awarded four grants worth $1.18 million under this program to stimuate public service uses of satellite communications. This program is to carry out the NTIA's role in stimulating the aggregation of the public service market. The grantees were the Appalachian Community Service Network (ACSN, see below for details) Bell & Howell, PSSC (Public Service Satellite Consortium, see below for details) and American Educational Television Network [AETN].

---

[79] Testimony of Dr. John H. McElroy, NASA, before the Subcommittee on Transportation, Aviation, and Communications and the Subcommittee on Science, Research and Technology of the House Committee on Science and Technology, May 21, 1980, pp. 2-3.

[80] Press release from the Office of the White House Press Secretary, Oct. 11, 1978, "U.S. Civil Space Policy (PD 42)," p. 2.

In announcing the grant awards, the Administrator of NTIA noted that the grants were "a major step in bringing the benefits of the national investment in satellite technology to the public sector."[81] The ACSN grant has enabled ACSN to expand its satellite cable network, which had offered instructional programing primarily in Appalachia, to include national public service applications. The Bell & Howell Co. grant is for developing a civic affairs network to be used by public service organizations and Federal agencies for training, education, teleconferencing, and community outreach. The PSSC grant is for continuation of its efforts to stimulate public service satellite uses. The AETN grant is for transmission of continuing education programing to professional associations and employee organizations, helping to meet State licensing and college credit requirements.

One feature of the NTIA grant program is cooperation among the grantees to help form an integrated national system of public service telecommunications. The grants are not demonstration grants. Rather, they are seen by NTIA as a first step toward fully operational systems which will meet public service needs.[82]

3. NASA role

Public Service Communications is one of the three major elements in the NASA communications program at the present time and encompasses a number of activities. The first of these is the continued operation of ATS-1 and ATS-3; the second is the international search and rescue program (see below for details); the third is participation with other Federal agencies to aid them in performing their assigned missions (NTIA, AID, and the Federal Emergency Management Administration); the fourth is continuing efforts to transition the user community from operation on NASA experimental satellites onto commercial satellites (primarily PSSC and ACSN); and the last study of innovative ways to serve public users by advanced satellite communications.

F. PUBLIC SERVICE SATELLITE CONSORTIUM [PSSC]

1. Origin

Communications experts, educators, and health care specialists had been excited by the public service experiments conducted on ATS-6 and their potential for solving public service needs. When ATS-6 was relocated to service India during its second year, U.S. domestic experimenters had no mechanism to apply what they had learned on ATS-6. Encouraged by HEW, NASA, and the White House Office of Telecommunications Policy, a number of nonprofit institutions that were interested in noncommercial uses of satellite communications (i.e. for education, health care, religious and library communications, for public broadcasting, and for State telecommunications) formed the Public Service Satellite Consortium (PSSC) in March 1975. The intent was, through PSSC, to aggregate the large number of small, diverse public service users into an operational unit which could share the risks and take advantage of economies of scale. By so doing, PSSC members hoped they could benefit by improved services and lowered costs.

---

[81] NTIA TPR 80-36. Commerce Department. "Funds For New Satellite Communications Networks," July 22, 1980, p. 2.

[82] Ibid.

Startup financing was provided by a $475,000 grant from NASA and the Department of Health, Education, and Welfare plus membership due of $500 per year. The terms of the founding grant stipulated that PSSC take over the NASA transmission facilities in Denver and Morrison, Colo., which had been used for the health and education experiments on ATS-6. Those facilities have formed the core of PSSC's technical facilities.

Starting with some 23 nonprofit organizations in 1975 (including public service agencies, professional societies, universities, States, and a range of subconsortia), PSSC membership has grown to over 100 institutions in 1981. Membership is diverse, ranging from the Corporation for Public Broadcasting, the Public Broadcasting Service, and the National Public Radio to the American Medical Association and the American Bar Association to States to the National Education Association, the U.S. Catholic Conference and the Southern Baptist Conference.

Though startup financing was obtained from the Federal Government, PSSC has since been supported by its membership fees, revenue from the annual conference, and fees from services performed under contract to members and others. For fiscal year 1981 (the latest year for which this data is available at this time), these sources of income provided about two-thirds of the PSSC revenues.[83] A continuing contract with NASA, the "applications pilot test" and the NTIA public telecommunications service grant comprise the remainder.

2. Bridging the gap between experimental and operational

The intent of PSSC was to move public service satellite telecommunications from the experimental to the operational stage. Thus, the first few years of PSSC operation were used to explore experimental and operational satellite systems and their value of PSSC members. Some PSSC members participated on ATS-6 and some on CTS (the joint United States/Canadian Communications Technology Satellite) while others used commercial satellites. Because both ATS-6 and CTS were experimental, they could not service PSSC's longterm needs. Thus, from the beginning PSSC was examining the possibilities in renting transponder space on commercial communications satellites and on possibly defining their own dedicated satellite system.

One possible way to bridge the gap between experimental ATS-6 and CTS and a future PSSC satellite system or NASA experimental communications satellite, was explored in the late 1970's: The Hughes Aircraft Co., Syncom IV satellite. Syncom IV was a space shuttle optimized communications satellite proposed by Hughes for launch during the shuttle flight test program. Syncom IV was perceived by some as a "gapsat" to cover the period between ATS-6 and CTS and a follow-on operational service. In September 1977, PSSC and Hughes reached an agreement for PSSC to define a communications payload for Syncom IV which would satisfy the aggregated requirements of public service users.

---

[83] PSSC president' report, board meeting and annual membership meeting, October 1980.

Hughes had proposed the idea of a public service communications package on Syncom IV if (1) a package of Federal and private funding could be assembled; (2) if launch negotiations for an orbital flight test launch could be completed successfully; and (3) if cost questions could be resolved. Such arrangements were not satisfactorily resolved, and by spring of 1978, NASA had decided that near-term public service satellite communications and demonstrations could be carried out by leasing available service from common carriers.

Though long term consideration of a dedicated public service satellite remains a possibility, PSSC currently services its members operational needs through leasing of transponder space on existing commerical communications satellites.

3. PSSC services

Through aggregation of the public service market, and through a number of specific services to the public service user community (both members and nonmembers), PSSC has been quite successful in enabling public service telecommunications needs to be met.

PSSC serves to aggregate the diffuse public service market in the following ways: (1) it aggregates requirements so maximum use of facilities and software can be made, thus enhancing feasibility of activities and minimizing costs; (2) it aggregates resources in order to spread costs over a broader base; (3) it enables bulk arrangements for facilities so that initial costs are minimized; and (4) it provides a mechanism for cooperative, aggregate decisionmaking which would otherwise not be feasible for individual organizations.[84]

PSSC carries out a number of services for its member organizations. It conducts studies and needs assessments; performs a variety of consulting services; represents the needs and interests of its members on telecommunications issues before policymaking bodies (the Congress, the Federal Communications Commission, the International Telecommunications Union); develops cost models for delivery of telecommunications services or systems required by the members; provides technical assistance ranging from system design to operating services through the Denver technical group office and satellite access facility; provides complete teleconferencing services through its national satellite network.

4. Technical facilities

Though PSSC headquarters is in Washington, D.C. its technical services originate in the technical group offices in Denver, Colo. PSSC technical facilities are outlined below.

---

[84] Bransford, Louis A. "Aggregation of a Public Service Satellite Market," Satellite Communications, August 1978: p. 42.

a. *Denver satellite access facility.*—This facility consists of a television studio designed for production of video-teleconferences, a network control center, and a 36-foot Earth station capable of accessing all domestic commerical satellites. This office is located in Morrison, Colo., and is linked by microwave to the Denver technical group office.

b. *Transportable Earth Station [TES].*—PSSC built, operates, and leases the TES, used for remote site transmitting and receiving at both 6/4 GHz (C band) and 14/12 GHz (Ku band). TES contains equipment enabling it to be used as a mobile television production facility (2 color cameras, a control console, monitors and auxiliary equipment for remote origination). TES became available in August 1980 and is capable of accessing all domestic commercial satellites and can deliver audio, video, and data services to areas formerly inaccessible for satellite transmission and reception. The complete TES is mounted on a trailer which measure 34 feet by 8 feet.

c. *National satellite network [NSN].*—In late 1978, following several years of experimentation in teleconferencing and program distribution through Federal-subsidized programs, PSSC started its prototype National Satellite Network (NSN). NSN is a videoteleconference service through which PSSC contracts with various commercial satellite systems to provide public service groups with teleconferencing capabilities. The first test of the system was in September 1978 when the American Dietetic Association distributed an educational program via a commercial satellite (Westar I) to dieticians in about 100 locations in the United States.

By June 1979, NSN was a fully operational component of PSSC. NSN is administered from PSSC's headquarters in Washington, D.C., and supported by the operational staff in Denver. At this time, PSSC has carried out more than 85 teleconferences through its NSN. Users have ranged from the AFL-CIO to the United Methodist Church.

NSN can be tailored to each client's needs to provide new opportunities for communications. Its applications include delivery of continuing professional education; teleconferencing for planning, instruction, advisory and administrative functions; audio/visual materials distribution; and special events such as conferences, seminars, workshops, and symposia. NSN makes available the user networking services, including acquisition of satellite time, coordination of terrestrial facilities, and management of the event.

d. *Ku-band Earth station network.*—The CTS program (see above) used ground station equipment designed for operation at the Ku-band (14/12 GHz). When CTS was retired in 1979, this ground equipment also had to be retired because U.S. satellites at the time operated at 6/4 GHz. With the recent launch of SBS 1, a Ku-band satellite and the Candian ANIK B, also a Ku-band satellite, ther are two satellites which could be used with this ground equipment. PSSC is under a contract with NASA to develop a network of satellite Earth stations operating at Ku-band. PSSC will establish and manage this network utilizing the Ku-band Earth station equipment provided by NASA or acquired by public service users for use with CTS. This satellite network would then be used for public service applications and supported by public service organizations.

e. For-profit subsidiary.—PSSC has always been a non-profit organization. However, during its more than five years of operation, PSSC has received numerous inquiries from the business sector about using its services. In order to best serve those clients, PSSC has incorporated a for-profit subsidiary (in June 1981) called Services by Satellites (SatServ). This subsidiary will enable PSSC to perform the same services for corporate clients that it does for non-profit organizations without endangering its non-profit status. It will also allow PSSC entry into new lines of business. Anticipated services by SatServ are consulting, brokering and networking of satellite services, facilities rental, publishing, contract management and organization of workshops and seminars. SatServ became operational on October 1, 1981. After-tax profits of SatServ will accrue to PSSC, thus constituting a significant source of revenue to PSSC and enabling further service to its members in provision of public services.[85]

G. APPALACHIAN COMMUNITY SERVICE NETWORK [ACSN]

The ACSN, along with the PSSC, is a major public service organization using satellite communications to meet public service needs. ACSN, founded in September 1979, grew out of a five year program called the Appalachian Education Satellite Program (AESP) which used ATS-6 to deliver community service broadcasting in rural Appalachia. ACSN was founded to expand the activities of the AESP. ACSN now distributes educational and public service programing for about 70 hours a week via the RCA Satcom I satellite. NASA aided the transition from ATS-6 to Satcom by helping ACSN to obtain an uplink terminal and additional receive-only terminals, and to convert existing terminals from S-band (used by ATS-6) to C-band (commercial). The non-profit ACSN has been using Satcom I since October 1979 to make public service programing available. Though the program started in Appalachia, ACSN is now available through cable systems nationwide.

VII. SEARCH AND RESCUE SATELLITE

A. THE SEARCH AND RESCUE SATELLITE [SARSAT] PROJECT

1. Project background and rationale

In an experiment designed to prove a new method of locating ships, boats, and aircraft in distress, the international Search and Rescue Satellite-Aided Tracking [SARSAT] package will be launched onboard three NOAA weather satellites, beginning in 1983.

The Sarsat payload will be included on the advanced TIROS N-class spacecraft NOAA E, scheduled for launch in February, 1983. It will not be included on the following satellite, NOAA D, in August, 1984, but wil be on the two NOAA satellites following that—NOAA F and NOAA G—currently scheduled for launch at 18-month intervals following NOAA D.[86]

---

[85] Public Service Satellite Consortium press release, "PSSC Board Votes to Incorporate For-Profit Subsidiary," 1981.

[86] NOAA E will be launched before NOAA D in order to get the Sarsat system up as soon as possible. See chapter Four for a discussion of U.S. weather satellites.

If the Sarsat system is proved successful in a demonstration and evaluation phase lasting 15 months after the first launch, a 5-year operational evaluation phase will begin, which will provide continuous Sarsat service. It is expected that three more NOAA satellites would be Sarsat-equipped (NOAA H, I, and J) during a transition period between testing and international operational use.

The Soviet Union's search and rescue satellite, Cospas, is being synchronized with the American-Canadian-French-Norwegian Sarsat effort to form the international Cospus-Sarsat project.

The idea of a search and rescue system aided by satellites is as old as the U.S. space program. As early as 1959, NASA and the Defense Department's Advanced Research Projects Agency [ARPA] received a proposal from the Space Electronics Corporation to equip a satellite with radio receiver/transmitters to pinpoint the locations of downed ships and planes.[87]

The rationale for such a device was then, and is now, to make rescue operations faster and more accurate. Speed is of obvious importance to plane crash and shipwreck victims. While the chance of survival for plane crash victims is less than 10 percent if the rescue is delayed beyond 2 days, the survival rate is a better than half if a rescue team arrives within 8 hours. Quick and accurate location of vessels in distress also cuts down the cost and danger to rescue parties, especially in such wild and inhospitable regions as the mountains of Alaska.[88]

Currently, search and rescue efforts rely heavily on the detection of emergency radio signals from ships and planes in disress by overflying aircraft or ground stations within radio range of the distress signals. In 1981, some 200,000 aircraft were equipped with Emergency Locator Transmitters [ELT's] automatically activated by an aircraft crash, and 6,000 marine vessels carried the equivalent device for ships, the Emergency Position Indicating Radio Beacon [EPIRB]. Congress has required the installation of ELT's on general aviation aircraft since 1974.[89] EPIRB's are required on ocean-going vessels inspected by the Coast Guard, and are recommended for use on all private ships and boats.

However, there exists no system to continually monitor these beacons. On long overwater flights, the International Civil Aviation Organization requires that airplanes monitor the 121.5 Megahertz (MHz) emergency frequency to listen for distress calls, but this affords only minimal coverage of the vast ocean expanse, and no such regulations exist for domestic flights.[90]

Even if the signals are received, there is little assurance of accurately or quickly locating the emergency site, or even of being certain that there is an emergency. Because they provide no more information than the signal iself, existing emergency transmitters generate a large number of false alarms. In addition, whoever receives the distress call may not be equipped with direction-finding equipment to pinpoint an exact location.

---

[87] Aviation Week and Space Technology. June 29, 1959.

[88] National Aeronautics and Space Administration. Office of Space Science and Applications. Cospaas-Sarsat System Summary. Unpublished. December, 1981. P. 2-1.

[89] U.S.C. 49 § VI—Safety regulation of Civil Aeronautics. Section 1421(d)(1).

[90] Testimony of Dr. John McElroy, U.S. Congress. House. Committee on Science and Technology. Subcommittee on Transportation, Aviation and Communications and Subcommittee on Science, Research and Technology. Communications Research and Development. Hearings, 96th Congress, 2d session. May 20, 21, 22 and 28, 1980. Washington, U.S. Govt. Print. Off. 1980. p. 159

In 1975, the U.S. Department of Transportation cooperated with Canada and the Federal Republic of Germany in an experiment using NASA's ATS–6 Applications Technology Satellite to test the concept of satellite relay of distress signals.[91] For this test, an emergency radio beacon was successfully transmitted from a vessel in the mid-Atlantic Ocean, relayed through ATS–6 to a ground station, then forwarded to a shore-based Coast Guard rescue center.

Another satellite-aided concept was GRAN [Global Rescue Alarm Net], which underwent some preliminary testing by the U.S. Navy in 1973.[92] GRAN was limited, though, by the ambiguity in location of signals by the Navy's Omega navigational stations, and by its reliance on geosynchronous satellites. These stationary satellites, located over the equator, would be ineffective in receiving distress signals from polar regions or from the "shadow" side of a mountain, and would not be able to pinpoint a signal's location by means of Doppler tracking as can low-orbit satellites. The GRAN concept was therefore discarded before it was even tested fully, in favor of systems that use the constantly moving low-orbit polar satellites.

Other experiments using the AMSAT OSCAR satellites during 1975 and 1976 further demonstrated the validity of the satellite-based search and rescue concept.[93] In 1973, an Interagency Committee for Search and Rescue [ICSAR] was formed, with membership including NASA, the Departments of Commerce, Defense and Transportation, the Federal Communications Commissioin, and various non-government organizations such as the Aircraft Owners and Pilots Association [AOPA] and the National Association for Search and Rescue. As the result of study it conducted in 1976, ICSAR recommended that a search and rescue satellite demonstration be implemented.

Joint United States-Canadian efforts following that study led to the definition of the Sarsat mission, which NASA presented to the Congress as a new start for fiscal year 1978, with a budget request of $5.6 million for that year. In congressional budget hearings, Sarsat was presented as an interagency venture in cooperation with the Canadian govenment, which was to pay approximately half of the project's total estimated cost of $30 million.[94]

Sarsat funds were appropriated by Congress at comparable levels to 1978 for the next 3 years, with a peak of $8 million in 1979. In 1981 the Sarsat budget was the subject of debate in Congress when NASA submitted its request for fiscal year 1982 funding. The original request included funding for the initial 15-month Sarsat demonostration phase, as well as funds for the project's continuation after that, in a 5-year "operational evaluation phase".

Following President Reagan's assumption of office in January 1981 a revised Sarsat budget request was presented. The new request maintained the $1.3 million for the first Sarsat launch and subsequent 15 months of tests and evaluation, but deleted the money for other Sarsat launches as well as the operational evaluation phase.

---

[91] "Search and Rescue Satellite-Aided Tracking System," American Astronautical Society paper No. 80–204, p. 1. The ATS–6 satellite is discussed in section 6 of this chapter.

[92] General Aviation News, Dec. 24, 1973.

[93] "Search and Rescue Satellite-Aided Tracking System," American Astronautical Society paper No. 80–204, p. 2. OSCAR satellites are discussed further in section VIII of this chapter.

[94] Since that time more partners have joined in the Sarsat program. The estimated costs have risen, though, and in 1981 NASA estimated that their share of expenditures by project's end will be about $24 million.

In testimony and questioning following this revised request, Representative Ronnie Flippo, chairman of the Subcommittee on Space Science and Applications of the House Science and Technology Committee, expressed concern over the wisdom of conducting a "limited duration experiment with no plans for converting a successful demonstration to an effective operating system".[95]

When asked if the trimming of the Sarsat program would adversely affect U.S. partners in the international Cospas-Sarsat venture (at that time Canada, France, and the Soviet Union), NASA's Samuel Keller testified that "the NASA decision will lead to the loss of significant contributions by our Cospas-Sarsat partners".[96]

With these considerations in mind, the final authorization bill for NASA restored funding for a continued Sarsat program to the 1982 budget.

As the Sarsat program has moved closer to its first launch, other nations have joined with the United States and Canada as participants. They are France (joined 1977), the Soviet Union (1980), and Norway (1981). This international cooperation is described in more detail below.

2. Technical description and Sarsat management

The Sarsat concept is to use satellites as relays for the retransmission of distress signals from aircraft or ships to Rescue Coordination Centers on the ground. The system thus has three elements, beginning with the emergency transmitters themselves. Ships and planes will carry the ELT's or EPIRB's operating either on existing emergency frequencies of 121.5 and 243 MHz, or on the new experimental Sarsat frequency of 406 MHz.[97]

In space, there will be an antenna, receiver, processor, and transmitter capable of receiving and processing the emergency signals. These will be carried on each of several NOAA meteorological satellites in near-polar orbits at 850 kilometers altitude. On the ground will be a number of stations capable of processing this relayed signal for forwarding to rescue coordination services.

The Sarsat system will operate in two modes—regional coverage and full-orbit global coverage. For regional coverage the spacecraft will receive signals at any of the three frequencies (121.5, 243 and 406 MHz) and amplify them for relay to local user terminal (LUT) ground stations located at Scott Air Force Base, Ill; Kodiak Island, Alaska; or Point Reyes, Calif. There will also be an LUT station located near Ottowa, Canada, and one each in France and Norway, and those operated in the Soviet Union under the Cospas system.

---

[95] U.S. Congress. House. Committee on Science and Technology. Subcommittee on Space Science and Applications. 1982 NASA authorizations. Hearings, 97th Congress, 1st session, Mar. 12, 17, 18, 19, 20, 21, 23 and 24, 1981. Washington, U.S. Government Printing Office, 1981. p. 2468.

[96] Ibid.

[97] The 406 MHz band was allocated for low-power ELT-to-spacecraft communications by the 1971 World Administrative Radio Conference held by the International Telecommunications Union.

This real-time regional coverage requires that both the emergency transmitter and the LUT station be within radio sight of the passing satellite. With the combined coverage afforded by the four North American LUT stations, however, no area in the continental United States (including Alaska) would ever be out of that triangle of sight. An LUT station would receive the relayed distress call from the first satellite to pass by the emergency site, with the time between passes dependent not only on the latitude of that site, but on how many satellites are in orbit. Assuming only one Sarsat satellite, the maximum time between successive detections at the equator would be 12 hours, with more frequent coverage closer to the poles. The joint Cospas-Sarsat program calls for at least two such satellites in orbit at any one time.

After receiving the relayed distress signal from the satellite, the LUT station would compute the location of the airplane or boat as extracted from measured Doppler shift of the signal, and would immediately send distress calls to the appropriate Air Force or Coast Guard Rescue Centers.

Although Sarsat satellites will be sensitive to distress calls from existing 121.5 and 243 MHz emergency transmitters, these frequencies are not optimal for satellite detection, since they were designed to be received by aircraft or ground stations. The 406 MHz experimental transmitters are therefore a key component of the Sarsat system. Not only will this frequency be better suited to satellite communication, it will also be much more effective in relaying information valuable to search and rescue operations.

These beacons are designed to transmit every 50 seconds a relatively strong (5-watt) short burst signal composed of a pure carrier preamble, followed by a digitally coded message. The message can include such information as identification of the ship or plane in trouble, the nature of the emergency, or, as options, the time elapsed since the emergency occurred or the last known position. The 406 MHz transmitters will greatly outperform the lower frequency transmitters, and the probability of detection of normally transmitted signals would be 95 percent.[98] The location accuracy would be two to 5 kilometers, as opposed to the 10–20-kilometer accuracy expected for the lower frequency transmitters.

The Sarsat concept calls for gradual phasing in of these more effective 406 MHz units as they are bought by aircraft and shipowners to replace older equipment. Expected cost of 406 MHz units is about $500. At the same time as the user community is phasing in the new 406 MHz units, emergency locator Sarsat service would continue at the established lower frequencies.

The full-orbit global coverage mode can operate only in the 406 MHz band. This system will provide worldwide coverage by storing information from an emergency transmitter for processing on board the spacecraft and later transmission to the ground when the satellite comes within range of a control and data acquisition (CDA) station in Alaska or Virginia. The satellite's onboard processing includes measuring the Doppler shift for finding location, recording the time, and handling any coded messages included in the 496 MHz band transmission. The CDA station would then forward this information to one of the international Mission Control Centers [MCC] located in the United States, Canada, France, and the Soviet Union, which would then alert appropriate Rescue Coordination Centers [RCC] in its own country. The United States Mission Control Center is at Scott Air Force Base in Illinois, which also has an LUT ground station. This storage of 496 MHz signals for later transmission to ground stations insures that a distress call will eventually reach a rescue center, even if it isn't within real-time regional coverage range.

---

[98] NASA Cospas-Sarsat system summary, pp. 3–7

The Sarsat experiment is thus two experiments in one—an experiment using low-frequency transmitters, and one involving the improved 406 MHz beacons. Present plans call for a 15-month demonstration and evaluation period following the launch of the first Sarsat early in 1983. Since the Soviet Union plans to launch its interoperable Cospas 1 in mid-1982, there will be two search and rescue satellites in orbit during this tesing period.

The 15 months of testing includes 3 months of system checkout followed by a year of user evaluation. This will be a cooperative effort by the four agencies that signed a memorandum of understanding concerning Sarsat on December 21, 1978. NASA has overall management responsibility for the project, while the National Oceanic and Atmospheric Administration (NOAA) is in charge of operating the weather satellites on which the Sarsat rides. The U.S. Coast Guard is responsible for evaluating the Sarsat's effectiveness in maritime rescue, while the Air Force performs the same function for air rescue operations.

Evaluation test will include not only simulated rescues, but also actual disasters, and so the system will be used "operationally" in effect, very early. Rescue services will evaluate Sarsat's impact on personnel workloads, and will participate in tests of the Canadian Local User Terminal [LUT]. Following the testing phase, a 5-year operational evaluation program will assess the factors involved in making Sarsat an operational system with its own funding and administrative requirements.

B. INTERNATIONAL PARTICIPATION IN THE COSPAS-SARSAT PROJECT

1. The Sarsat partnership

Canada has been involved in the development of the Sarsat project since its inception. When NASA requested funding to start up the program in fiscal year 1978, it was understood that Canada would be a full partner sharing equally in the project's cost. Cooperative efforts led to the formal signing of a memorandum of understanding between the two nations in 1979. Canada contributes the operation of an LUT station near Ottawa, and also supplies the spaceborne repeater instrument, which relays signals from ELT's and EPIRB's in any of the three designated wavelengths in real time.

The French government expressed an early interest in the Sarsat venture. Meetings with NASA in 1977 led to France's joining the project as the third partner, and this was formally agreed to in that same memorandum of understanding signed by the United States and Canada on August 24, 1979. The three countries at that time agreed to conduct the demonstration and evaluation phase of Sarsat.

Through the Centre National d'Etudes Spatiales [CNES], France is contributing the satellite-borne receiver and preprocessor unit, in addition to supplying its own ground segment. This receiver-processor, a similar technology to the Argos data collection and platform location system flown on the TIROS N-class weather satellites, will be critical to the experimental use of the 406 MHz emergency signals. The processor gives Sarsat its capability to handle coded messages from ships and planes in distress.

In November of 1981 Norway also joined the Sarsat program as an investigator, meaning that Norwegian ships and aircraft will carry experimental transmitters to participate in evaluating the system's usefulness. Norway will also operate an LUT ground station.

At the end of 1981, Japan, Sweden, and the United Kingdom had all expressed interest in joining as Sarsat investigators, and negotiations were in progress. The Sarsat-Cospas nations remain open to participation by additional countries and international organizations, provided that they: (1) add no costs to the parties already involved; (2) be compatible in scheduling and technology with the Sarsat and/or Cospas; (3) contribute to the objectives of the parties invovled; and (4) offer a significant involvement by users.[99]

The international SARSAT partnership is expected to continue toward the goal of defining a worldwide operational system following the initial 15 months of testing.

2. Soviet involvement in Cospas-Sarsat

The involvement of the Soviet Union in the search and rescue satellite project is a special case. Like France, the Soviet Union expressed interest in the concept very early, during NASA/Soviet discussions in 1975 and 1976, as one area of potential cooperation with the United States in future space activities.[1]

Meetings in 1977 with the Soviets on the technical aspects of the (then) United States and Canadian venture were held, and the Soviets expressed a desire to equip their own satellites with search and rescue equipment.[2]

In a protocol confirmed May 18, 1977, NASA and the Soviet Ministry of Merchant Marine agreed on Soviet participation in the Sarsat project. The Soviets would provide and launch one or more search and rescue satellites on the same schedule as the Sarsat lauches. The Soviet system called Cospas, would be fully compatible technically with the Sarsat ground and space technologies, but each side would conduct its own search and rescue operations and would be responsible for maintaining its own ground stations. It was agreed that the Soviets would participate in testing the 406 MHz signal as well as the lower frequency radio transmitters, and their own ground stations would be capable of receiving stored transmissions.

---

[99] Ibid. P. 7-2

[1] Aviation Week and Space Technology, Mar. 26, 1977

[2] U.S. Congress. Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Science, Technolocy, and Space. 1979 NASA authorization. hearings, 95th Congress, 2d session. Mar. 8 and 10, 1978. Washington, U.S. Government Printing Office 1978. p. 953

A memorandum of understanding was formaly signed between the Soviet Union and the Sarsat parties on November 29, 1979. This is the essence of the Cospas-Sarsat agreement as it stood at the end of 1981—two fully interoperable systems conducted independently by each side. Soviet satellites can receive and process Sarsat distress signals, and vice versa, giving a better alert and response time than either system would have acting alone.

The Soviets plan to launch the first Cospas in mid-1982, and so will precede the first Sarsat launch by several months. Like the Sarsat space segment, the Cospas instruments will fly as shared payloads on Soviet polar orbiter satellites, to be placed in orbits complementary to the NOAA satellites for maximum effectiveness of coverage. Like Sarsat, the Cospas launches will be sequential.

In congressional testimony on the NASA budget for fiscal year 1981, Administrator D. Robert Frosch was asked how President Carter's embargo on various relations with the Soviet Union would affect the Cospas-Sarsat partnership. He answered:

> With regard to the search and rescue satellite arrangements, we would not expect them to be affected. That is an arrangement which is constructed in an unusual way. There is a multilateral arrangement among the United States, Canada and France to do a cooperative program in search and rescue satellites.
>
> The Soviets asked whether they could join that multilaterial arrangement. The three parties agreed that that could be done, and so the three parties have signed an agreement with the Soviets to participate in the experiment. But the nature of the participation is such that there is no exchange of technoology with the Soviets and no exchange of funds. They will fly some search-and-rescue satellite experiments at about the same time that we are flying ours, and the whole thing has a humanitarian aspect to it. So I would expect that that particular arrangement, since it is a kind of arms-length arrangement, would continue.[3]

The "arms-length" arrangement is also constructed in such a way that, should either side withdraw unilaterally, the other side could continue its own program as it was originally designed, affected only by the reduction in frequency of satellite coverage.

Despite the similar cancellation by President Reagan of Soviet-American ventures in 1981, the Cospas-Sarsat program was not affected, and remained on schedule for a Soviet launch in mid-1982 and a U.S. launch in February, 1983.

VIII. ORBITING SATELLITE CARRYING AMATEUR RADIO [OSCAR]

OSCAR's (Orbiting Satellites Carrying Amateur Radio) are communications satellites designed and constructed by radio amateurs on a nonprofit, nongovernmental basis. They are designed for noncommercial public service and educational use by the amateur radio community. They ride piggyback on launches of other satellites, replacing the dead weight ballast ordinarily used to adjust the weight of the uppermost booster stage. Early OSCARs were designed to give radio amateurs experience in tracking and tuning in signals from orbiting satellites. However, emphasis has shifted to building satellites which are capable of receiving and retransmitting communications signals. Now, amateurs in over 100 nations actively transmit and receive through the OSCAR satellite services.

---

[3] U.S. Congress. Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Science, Technology, and Space. NASA authorization for fiscal year 1981. Hearings, 96th Congress, 2d session. Feb. 6, 7 and 20, 1980. Washington, U.S. Government Printing Office 1980. p. 1055

A. HISTORY

When the Soviet Union launched Sputnik on October 4, 1957, owners of general coverage receivers discovered that they could tune in the 20 MHz beacon signals of the satellite as it passed overhead, thus demonstrating that a beacon satellite operating in the amateur bands was feasible. The National Aeronautics and Space Administration [NASA] agreed that such a satellite could be carried aboard a regularly scheduled launch in place of the ballast normally used. A group of California amateur radio operators began work and developed OSCAR 1, the world's first nongovernmental satellite.

B. PHASE I SATELLITES

Phase I of the amateur satellite program was represented by OSCARs 1–5. These were short-lifetime satellites whose purpose was to familiarize radio amateurs with satellite tracking techniques. OSCAR 1 was launched into a polar orbit on December 12, 1961 from Vandenberg Air Force Base in California. The OSCAR 1 satellite transmitted the message "HI", the traditional Morse code expression for laughter. Although it had a power output of only 100 milliwatts, more than 5,000 reception reports were received from 28 countries during the 20 days OSCAR 1 operated.

OSCAR 2 was launched on June 2, 1962, and was essentially identical to OSCAR 1. The success of the first two OSCARs led to the development of a true communications satellite. The result was OSCAR 3, the world's first free-access, active communications satellite, launched March 9, 1965. OSCAR 3 accepted signals from Earth and retransmitted them with a power output of one watt. Nearly 100 amateur stations in 16 countries used OSCAR 3, and many records were established during its 15-day lifetime. The first trans-Atlantic amateur contact via satellite was made through OSCAR 3. It provided the first direct communications via satellite for Belgium, Bulgaria, Canada, Czechoslovakia, Finland, Israel, Sweden, and Switzerland.

OSCAR 4; launched on December 21, 1965, was the first amateur satellite to use a repeater that covered two different bands. Unfortunately, a launch vehicle malfunction placed it in a highly elliptical orbit with a very low perigee. Only a dozen confirmed two-way contacts were made before the satellite re-entered the atmosphere and disintegrated. However, one of these contacts was the first direct satellite communication between the United States and the Soviet Union.

OSCAR 5, designed and built in Australia, was the last of the phase I OSCARs and was launched on January 23, 1970. Although it was not a relay satellite, it was used to test several new control and transmission systems that would play an important part in later OSCAR missions.

C. PHASE II SATELLITES AND AMSAT

The Phase II series marked the development of long-life satellites for two-way amateur radio communications and experimentation. Included in the Phase II series are OSCAR 6, 7 and 8, which were built under the auspices of the Radio Amateur Satellite Corporation [Amsat].

Created in 1969, Amsat is a nonprofit scientific corporation established in the United States, and is open to membership to all radio amateurs and interested nonamateurs. Operating funds are obtained from donations, membership dues, and grants from organizations such as the American Radio Relay League [ARRL], the ARRL Foundation, and the International Amateur Radio Union. Amsat's purposes and objectives, as stated in its by-laws, are to: provide satellites that can be used for amateur radio communication and experimentation; encourage the development of skills and the advancement of specialized knowledge in the art and practice of amateur radio communications and space science; foster international good will and cooperation through joint experimentation and study; facilitate communications in times of emergency; encourage the effective and expanded use of higher frequency amateur bands; and disseminate scientific, technical, and operational information derived from such communications and experimentation.

Demonstrating the increasing international character of the program, OSCAR 7 subsystems were developed by amateur groups in Australia, Canada, and West Germany, as well as the United States. OSCAR 8 electronic subsystems were supplied by amateur groups in the United States, Canada, West Germany, and Japan.

D. OSCAR 9—UOSAT

The ninth OSCAR satellite was launched on October 6, 1981. Constructed primarily by students at the University of Surrey in Great Britain, OSCAR 9 (also called Uosat), is the first OSCAR to transmit data which is used by radio amateurs. The satellite has a voice synthesizer with a 150 word vocabulary that provides information about the spacecraft and its experiments, and also has a camera that produces images of the Earth which can be displayed on a standard TV set.[4] The camera has a resolution of 2 kilometers.[5] The satellite also carries a number of experiments for scientific research, including a series of radio beacons transmitting at different frequencies, two particle counters to provide information on solar activity and auroral events, and a magnetometer for studying the Earth's magnetic field. The experiments will assist in understanding how solar activity affects the transmission of radio signals through the ionosphere.

E. PHASE III SATELLITES

Phase II OSCAR spacecraft had some limitations; for example, they were designed for relatively low orbital altitudes, below 1,600 kilometers (1,000 miles), and to communication periods of 25 minutes at a time. The Phase III satellites will exceed all previous OSCARs in operational capability and technical sophistication. Like their predecessors, Phase III OSCARs will travel in polar orbits, but will have an apogee of 36,000 kilometers (22,400 miles) over the North Pole. This high altitude will enable amateurs to communicate over a much greater distance—17,920 kilometers (11,200 miles)—providing as much access time as 10 optimally spaced OSCAR 7 satellites. Thus, all amateurs in the Northern Hemisphere will be able to communicate with each other. In addition, most amateurs will be able to use the Phase III satellite for approximately 14 to 16 hours per day.

---

[4] Joels, Kerry M. Air & Space, Summer 1982, p. 11-12.

[5] Uosat. Goddard Space Flight Center News, Sept. 28, 1981. p. 5.

The highly elliptical orbit was chosen because over 90 percent of the world's amateur radio users reside in the Northern Hemisphere. The perigee will be 1,500 kilometers (940 miles) over the South Pole. Thus, while in the Southern Hemisphere, the satellite will function much like the current OSCAR 7 and 8 satellites.

Phase III satellites will be easier to use than Phase II OSCARs. The slow movement of the Phase III satellite relative to the Earth will eliminate the need for complicated beam and rotor antenna systems for tracking. In addition, the Phase III spacecraft will have a greatly increased effective radiated power achieved in part through use of directional antennas on the satellite.

The first Phase III satellite was to have been launched in May 1980 by the European Space Agency's Ariane launch vehicle, but the satellite was lost when the booster malfunctioned. The next Phase III satellite, OSCAR 10, is now scheduled for launch in the fall of 1982.

TABLE 3-3

OSCAR LAUNCH SUMMARY

SPACECRAFT	LAUNCH DATE	COMMENTS
OSCAR 1	Dec. 12, 1961	Designed to familiarize radio amateurs with satellite tracking techniques. Operated for 23 days; transmitted a simple message, HI.
OSCAR 2	June 2, 1962	Essentially the same as OSCAR 1. Operated for 18 days.
OSCAR 3	Mar. 9, 1965	World's first free-access, active communications satellite. Operated for 15 days.
OSCAR 4	Dec. 21, 1965	Never attained intended orbit. Transponder was damaged during launch, but functioned for several weeks.
OSCAR 5	Jan. 23, 1970	First amateur satellite under active ground control. Not a relay satellite, but tested control and transmissions systems for future satellites.
OSCAR 6	Oct. 15, 1972	First satellite designed and built under AMSAT auspices. Operated for over 5 years. Used in tests to determine positions of emergency locator transmissions from downed aircraft.
OSCAR 7	Nov. 15, 1974	Subsystems developed by amateur groups in the United States, Australia, Canada, and West Germany under AMSAT auspices.
OSCAR 8	Mar. 5, 1978	Subsystems developed under AMSAT auspices by groups in the United States, Canada, West Germany, and Japan.
OSCAR -	May 23, 1980	Lost due to launch vehicle malfunction.
OSCAR 9 (UOSAT)	Oct. 6, 1981	Constructed in Great Britain, carries 150 word vocabulary voice synthesizer and Earth imaging camera.

Phase III satellites will make use of frequencies in the same general range as the Phase II OSCARs. This is in accord with AMSAT's policy of not rendering obsolete the equipment currently being used for OSCAR communication.

F. Experiments With OSCAR

Unlike most communications satellites, OSCAR is designed so that relatively simple, portable equipment can be used to communicate with it. OSCAR satellites have been used to teach students the mechanics of satellite communications, to handle emergency communications, and to test the search and rescue satellite concept currently under development by NASA and several other countries (see section VII).

Amsat, in conjunction with the American Radio Relay League, sponsors the OSCAR Education program, a service provided free to teachers at grade levels from elementary school to college. The program assists teachers in using OSCAR for practical demonstrations of course materials. Among the topics which OSCAR has been used to demonstrate are the fundamentals of spaceflight (orbits, launching, tracking), geography, communication concepts, wave theory, and mathematics.[6]

IX. DOMESTIC COMMUNICATIONS SATELLITES

A. Introduction

Only 20 years ago domestic communications satellites were a dream—still as much a dream as they had been to Arthur C. Clarke when he proposed in 1945 that a small radio transmitter and receiver could be suspended motionless over the Equator 22,300 miles deep in space.[7] After remaining a dream for its first 20 years, though, this idea has been translated over the last 20 years into an increasingly vital communications link serving radio, television, telephone, telegraph and newspapers. It seems to be one of those rare technological developments that is even more useful and efficient than anticipated. Its growth resulted from a complex of technological advances in rocketry, computers and communications, coupled with imaginative entreprenuers, and the critical support provided by the U.S. Government's space program.

Despite their apparent complexity, the basic principles involved in satellite communications are relatively simple. The Earth turns on its axis once every 24 hours; if one were to stand on the Equator, a stationary point in space relative to the Earth would seem to whistle past at 1,036 miles per hour.

Through the combination of gravity and centrifugal force, a device that flies in a circle at a constant height above the Equator, and far enough from the surface of the Earth that the force of gravity tends to equal centrifugal force, will appear to constantly hang over the same spot on the Earth. Moreover, if the device were a small radio or television station, then it would be possible to communicate over vast geographic regions of the world with the assurance of the key condition for optimum communications—a clear line of sight between transmitter and receiver unobstructed except by air and distance. This is the essence and the attraction of the so-called geosynchronous orbit first described by Clarke in 1945 and often labeled the "Clarke orbit." The problems translating the theory into a workable technology for space communications were enormous.

---

[6] Joels, op. cit.

[7] Voices from the Sky, appendix, Harper & Row, New York, 1965.

After determining such requirements for communications satellites as frequency, power, and weight, it was necessary for the craft to fly at a speed of 6,875 miles per hour, 22,300 miles above the Equator. A fundamental constraint on the operation of communications satellites was power. The batteries and solar power generation system could not support a large transmitter that would consume great amounts of power; it would only deliver between 5 and 10 watts. Think of how difficult it is to receive a television signal 100 miles away from a 100,000 watt transmitter, then consider the challenge of reception 22,300 miles away from a 5-watt transmitter. Reflect, too, about how to repair a broken component, as well as how to get the sophisticated and sometimes delicate technology to orbit in the first place. These challenges were solved by the convergence and advance of several technologies. Those solutions and the development of satellite communications that they permitted are one major civilian byproduct of the U.S. space effort.

B. A BRIEF HISTORY OF EARLY SATELLITE COMMUNICATIONS

1. The Moon

The momentum of technological innovation in communications that began during the last years of the depression and exploded during World War II continued into the postwar era. Change was promoted by an expanding economy, easy credit, new scientific developments, and an appreciation of the benefits of excellent communications. Immediately after the end of the war, the U.S. Army tried to hit the Moon with radar. On January 11, 1946, they succeeded.[8] Not to be outdone, the Navy tried to relay communications traffic by bouncing it off the Moon. The idea worked so well that for 4 years, from 1959 to 1963, they used the Moon as a passive relay for communications from Washington, D.C., to Hawaii.[9] These experiments prompted a host of developmental work in satellite communications.

2. SCORE

On December 18, 1958, the U.S. Air Force launched the world's first artificial active communicaitons satellite experiment. The satellite was built by the Army at Ft. Monmouth, N.J. Named SCORE [for space communications by orbiting relay equipment], it was battery powered, was capable of relaying data, code, teletype, and voice, and it had an operating life of only 12 days.[10]

---

[8] NASA staff report, "Space Communications: Six Years of Achievement, 1958, through 1964." 7, Mar. 1, 1965.

[9] Ibid.

[10] Ibid, p. 13.

3. Echo

On August 12, 1960, NASA launched Echo I, a 100-foot diameter inflated balloon constructed of aluminum coated mylar. It could be seen from the ground because it was so large and highly reflective and because it orbited only 1,000 miles above the Earth. Echo provided important information despite the fact that it was simply a passive reflector. Good quality communications were accomplished by Bell Laboratories, and early developments in antenna and low-noise amplifier construction were tested and refined. Improvements were made in the pressurization system to assure a smooth surface and on January 25, 1964, Echo II was launched. The only other passive reflector of note to be used for communications experimentation, Echo II, like its sister, served primarily an experimental role.[11]

4. Courier

On October 4, 1960, the Army Signal Corps launched the Courier I–B. It weighed 500 pounds and was manufactured by Philco. It was powered by 20,000 solar cells and carried four transceivers and five tape recorders. It was capable of receiving and recording messages on one side of the globe during its 500- to 600-mile-high orbit, and retransmitting them at the appropriate time on the other side of the Earth. Unfortunately, Courier's operational life lasted only 18 days.[12]

5. Telstar

On January 19, 1961, the Federal Communications Commission authorized AT&T to launch its Telstar satellites. On July 10, 1962, employing much of the information learned during the Echo I experiment, AT&T launched Telstar I. It weighed 175 pounds and was a 34-inch diameter sphere. On its sixth orbit at 7:26 p.m. EDT, July 10, 1962, the first satellite television transmission occurred. During its 4-month useful life, it carried hundreds of transmissions, including over 50 television items in both black and white and color. Telephone calls, facsimile, and telephotos were also sent. After several months of difficulties, Telstar I went "dark" on February 21, 1963. On May 7, 1963, a nearly identical Telstar II was launched to serve the same function.[13]

6. Syncom and the geosynchronous communications satellites

On February 14, 1963, NASA launched Syncom I, the first attempt at placing a satellite in a geosynchronous orbit. It weighed 75 pounds and carried the first "apogee kick" motor and gas jet-positioning engines. These are the same rocketry tools use today to insert a satellite into a geosynchronous orbit, and to keep it there. By most estimates, the rocket machinery worked well. It achieved a nearly perfect synchronous orbit at an altitude of 22,300 miles. Unfortunately, 20 seconds after the apogee kick motor was fired to insert the craft into synchronous orbit, all communications failed and the craft, though later seen, was never heard from again. However, it prompted serious consideration of the benefits of synchronous orbits. For one thing, the antenna on the ground could be relativey inexpensive. If the satellite did not "move," then the antenna would not have to chase it across the sky. That dispensed with the need for an expensive motor and tracking system. A second, and vital, benefit was constancy. For the first time, a constant stream of communications could be relayed through the same spacecraft. If a constant, stable relay system were perfected, satellite communications would become dependable and the risk associated with commercial application would decline sharply.

---

[11] Ibid., pp. 10–11.
[12] Ibid., p. 13.
[13] Ibid., pp. 13–16.

On July 26, 1963, Syncom II was launched and become the first satellite to be maneuvered to a precise longitude, 55 degrees (west) which corresponds to that of Gander, Newfoundland. Syncom II weighed 86 pounds. The first satellite-borne telephone conversation between two heads of state occurred using this spacecraft between President Kennedy and Prime Minister Balewa of Nigeria. On August 19, 1964, Syncom III was launched and stationed at 180 degrees west which corresponds to the middle of the Pacific Ocean, precisely on the international dateline. Because of refinements in the launch vehicle that are still employed in synchronous satellite rocketry, Syncom III achieved a perfect orbit. Unlike its predecessors, it seemed to stay absolutely motionless in the sky.

While the Syncom series was not domestic, it was geosynchronous, and established that the United States was capable of orbiting a dependable geosynchronous communications satellite system. The real question was whether the policymakers and the communications industry were ready for the system.

C. A BRIEF HISTORY OF SATELLITE COMMUNICATIONS POLICYMAKING

1. *FCC docket 16495* [14]

It can be argued that the present structure of our domestic communications satellite industry was spawned by an application filed by the American Broadcasting Co., Inc. (ABC) on September 21, 1965. ABC proposed that they be licensed to operate a private nationwide satellite communications system as an auxiliary to their television network. Indeed, ABC contemplated that the regulatory custodian would be the Commission's Broadcast Bureau, not the Common Carrier Bureau. They wished to own it themselves and they were willing to pay $80 to $100 million to do it. They proposed that Hughes Aircraft Co. construct the spacecraft and that it have 24 video channels operating in the 4 and 6 GHz band. These channels would be used by all three networks as well as educational television, and ABC expected the annual operating expense to be about $17 million. The Communications Satellite Corp. [Comsat] opposed that application, arguing that the Communications Satellite Act of 1962 accorded them exclusive rights to the ownership and provision of domestic satellite communications services.

On March 2, 1966 the Commission returned ABC's application, "without prejudice." The Commission stated that it simply could not answer all of the novel policy and legal questions raised by ABC, that these questions could not be ignored and that it was launching an inquiry forthwith. On the same day, the Commission issued a notice of inquiry in docket 16495 regarding the Establishment of Domestic Communication-Satellite Facilities by Nongovernment Entities.[15] This notice triggered comments from a host of parties, many offering a plan for their own satellite system. The proceeding bogged down. But the parties to the proceeding continued to maneuver for position through their pleadings at the Commission.[16]

---

[14] 22 FCC 2d 86, 108 (1970).

On January 23, 1970, Peter Flanigan, then assistant to the President, wrote a letter to Dean Burch, then Chairman of the Commission, recommending a resolution of the questions raised in docket 16495.[17] To what extent Burch consciously followed the Flanigan letter is unclear. Only a portion of the recommendations found their way into the Commission decisions in docket 16495. However, over the years, nearly all of the recommendations have been employed, converting the letter into something of a regulatory checklist for domestic satellite communications. The Commission responded immediately by drawing together the information in the docket and drafting a memorandum of law which argued for diversity in the ownership and operation of satellite facilities.[18] On March 20, 1970, the FCC decided to open the skies to ". . . any non-Federal Government entity, including the Communications Satellite Corp., other common carriers, and noncarriers, to construct and operate (either individually or jointly) communications satellite facilities for domestic use." [19]

Comsat discovered that it possessed no statutory monopoly over domestic satellite services, and the telecomunications industry prepared for a "landrush" into space. The Commission now paused to seek comments and draft the rules governing the licensing process that would lend some order to this new and uncharted policy direction.

On June 16, 1972, the Commission issued its second report and order in docket 16495. It was a close vote which generated three dissents and one concurrence.[20] The Commission generally acknowledged that satellite communications services might not be less expensive than terrestrial services. They also understood that the quality might be inferior because of the delay inherent in satellite communications involving great distances from the ground to the spacecraft. Despite the fact that one of the networks was the original domestic satellite proponent (i.e. ABC), all three networks were now unsure how satellites might benefit them. Only cable television seemed the aggressor in promoting the use (as opposed to the provision) of communications satellites for unrestricted domestic applications. The Commission was uncertain about how these services would emerge once authorized to exist. The Commissioners were particularly troubled by the prospect of AT&T teaming with Comsat to create a state-of-the-art satellite communications system heavily subsidized by the monopoly revenues generated by AT&T.

---

[15] 31 Fed. Reg. 3507 (1966).

[16] See app. B.

[17] See app. C.

[18] See app. A.

[19] 22 FCC 2d 86 (1970).

[20] 35 FCC 2d 844 (1972).

Commissioner Johnson recommended that AT&T be permanently barred from satellite communications services.[21] Chairman Burch and Commissioners Reid and Wiley insisted that restrictions on AT&T were inordinately burdensome on Comsat, ". . . the one applicant with genuine experience in space segment management." [22] The Commission allowed all eight applicants to move forward, subject to certain conditions, as follows:

a. AT&T's use of domestic satellites would be limited initially to MTT, WATS, Autovon, emergency restoration in the event of terrestrial outage, and possibly other services in the case of Alaska, Hawaii, and Puerto Rico-Virgin Islands. It seemed that AT&T could only use satellites in circumstances where there could be clearcut benefits to the user, a relatively easy way for the Commission to monitor the activity, and in no event in those areas most susceptible to development by the other applicants.

b. AT&T would have the option of applying for authority to own and operate domestic satellite facilities, or of leasing transponders under tariff from Comsat or any other carrier who elects to proceed solely as a carrier's carrier. If one of the applicants carried any of AT&T's traffic, it suffered a permanent change in classification and, like AT&T, would be barred from other fields of satellite communications service. It could only be a carrier's carrier. This condition was particularly annoying to the three dissenters on the Commission because it applied to Comsat which they thought might be the only organization with the skills to do the job right. Other Commissioners were concerned, however, that AT&T owned 29 percent of Comsat's stock and held three chairs on its board of directors. AT&T's ownership interest in Comsat was later divested.

c. In the event Comsat should elect to proceed other than as a carrier's carrier, it would be prohibited from owning or operating domestic satellite facilities at any overseas point served by Intelsat facilities. There was concern that Comsat could otherwise suffer from an irreconcilable conflict of interest. This was largely reversed upon reconsideration.[23]

d. AT&T and other terrestrial carriers seeking domestic satellite authorizations would be required to submit for Commission approval, prior to action on their applications, a description of the kinds of interconnection arrangements they will make available to other domestic satellite systems or Earth station licensees. This was a control mechanism that withstood reconsideration.

Regarding the proposed satellite service to Alaska, Hawaii, and Puerto Rico-Virgin Islands, the Commission intended to integrate charges for services between those territories and the mainland into the domestic rate patterns. Toward this end, the Commission required timely submission of rates consistent with this policy, and opened the available services that could take advantage of the new satellite communications rates, including certain intraterritorial services. This aspect of the second report and order was largely unrevised by reconsideration. The Commission also invited tariffs that would give preferential treatment to educational services and institutions, and rejected proposals that it actually insist upon these preferential rates.[24]

---

[21] 35 FCC 2d 844, 867 (1972).

[22] 35 FCC 2d 844, 862 (Dissent of Chairman Burch in which Commissioners Reid and Wiley joined)(1972).

[23] See 38 FCC 2d 665, 688 (1972).

The race was now on to apply, license, construct, launch and operate domestic communications satellites. All of the critical administrative hurdles had been cleared, and the interested parties were free to pursue their goals.

While the Commission was engaged in the development of domestic satellite telecommunications policy, the Congress carefully monitored FCC actions in its oversight role. Although no congressional action was taken after enactment of the Communcations Satellite Act of 1962, few annual oversight hearings ignored the domestic communications satellite issue.[25]

2. Deregulation of domestic receive-only antenna facilities

When the FCC concluded its proceeding in docket 16495, it was troubled by the potential for interference with transmission and reception of signals both at the spacecraft and on the ground. The frequencies used for transmission were shared with terrestrial microwave services. The Commission concluded that mandatory prior coordination of terrestrial receiving facilities would be beneficial, in part because it would reduce the filing of petitions to deny applications for authorization of new facilities and encourage "various carriers to use the limited frequencies more effectively. . . ." [26] In other words, facilities on the ground that did nothing more than receive signals would be tightly regulated. As a consequence, early receive-only facilities were very expensive and were installed by common carriers for multiple use.

Private use came in 1975 with the Commission's consent for Florida Cablevision to construct and use a receive-only facility for its cable television system.[27] A host of applications followed, propelled by increasing deregulation. Later, the Commission permitted satellite distribution of an Atlanta television broadcast signal.[28] The Commission then authorized the use of small receiving antenna "dishes." [29] Then it rescinded the requirement that cable television operators demonstrate approval for the carriage of specific programing on the system prior to approval for satellite receive-only facilities.[30] Finally, in docket 78-374, the Commission eliminated mandatory regulation or licensing of antennas used only for receiving signals from satellites.[31] However, total deregulation was avoided because of the occasional need to protect the receive-only facility. The frequencies used for satellite communications are the same used for terrestrial microwave purposes and a mechanism was devised to award FCC protection, but only if the owner "licensed" the receive-only facility. The Commission could thereby protect the facility by refusing to license new microwave paths that would lie across the receive-only antenna.

---

[24] 38 FCC 2d 665, 699-70 (1972).

[25] See, for example, U.S. Senate Subcommittee on Communications, overview of the Federal Communications Commission, 92d Congress, Feb. 1 and 8, 1972, at 88-90., and U.S. Congress, Senate Subcommittee on Communications, overview of the Federal Communications Commission, 93d Congress, Feb. 22, 1973, at 62.

[26] Re specialized common carriers, 29 FCC 2d 870, 930 (1971).

[27] 54 FCC 2d 881 (1975).

[28] Southern Satellite Systems, 62 FCC 2d 153 (1976).

[29] American Broadcasting Cos., et al, 62 FCC 2d 901 (1977).

[30] 67 FCC 2d 339 (1977).

[31] Domestic receive-only satellite Earth stations, docket 78-374, 46 P&F Radio Reg. 2d 698 (1979).

3. Orbital positions and international communications policy

"Over-the-air" telecommunications ignore political boundaries. The Canadian Government simply cannot prohibit the intrusion of broadcast signals from Detroit, Buffalo, Rochester, Burlington, or Boston. This phenomenon is exacerbated by satellite communications because of their reach. At 22,300 miles above the Earth, one satellite can "see" roughly one-third of the inhabitable face of the globe. As a result, there is really no distinction between domestic and international satellite communications except that which is artificially legislated into existance.[32] For these reasons regulatory management of satellite communications was forced to evolve in critical part through an international agency. This responsibility fell to the International Telecommunications Union [ITU], an arm of the United Nations that could trace its existance to the International Telegraph Union founded in 1865. The ITU first considered space communications frequency allocations in 1959 when the United States proposed the assignment of ten satellite communications frequency bands. The ITU responded with interim allocations that endured until permanent allocations were awarded at the 1963 Extraordinary Administrative Radio Conference in Geneva. The allocations above 6 gigahertz (that is, 6 billion cycles per second) were finally awarded at the 1971 World Administrative Radio Conference on Space Telecommunications [WARC-ST], effective January 1, 1973. Thus, the issue of international allocation of frequencies was under control, but the issue of orbital slots was not.

Orbital slots correspond to territory. As a spectrum conservation measure, each satellite "reuses" the same frequencies. However, a certain amount of distance is required between each one to avoid intolerable interference with the others. Orbital spacing or "slots" were devised to eliminate this potential. The only question was how much territory should be allocated to each satellite. This territory is measured in terms of degrees of arc, at the equator, from a point at the center of the Earth. In other words, beginning at the center of the Earth and dispersed laterally along the equator, a 4-degree arc would mean the satellite would rest in the center of a piece-of-pie-shaped wedge, 22,300 miles into space, and the angle at the sharp point of the wedge at the center of the Earth would be 4 degrees. The amount of arc has a dramatic effect on the sophistication of the equipment on the ground. The more degrees in the arc, the lower the cost in using the satellite. Typically, the narrower the path of the signal, the larger the antenna needed. Antennae on the ground can be smaller with larger orbital slots because the signal does not have to be as narrow to avoid interfering with the next satellite.

As the Commission deliberated on its domestic satellite policy, it generally felt that 3 degrees was feasible under certain conditions.[33] However, there was no established policy, primarily because of an interest in preserving flexibility. The Commission established an elaborate licensing procedure, permitting it to approach the subject on an ad hoc basis each time an application was filed. This lasted until June 5, 1974 when it decided *Western Union Telegraph Co.*[34] Western Union wished to locate Westar IV at 119 degrees west longitude. RCA, AT&T, and Comsat objected, claiming that they were required to serve Alaska and Hawaii, that Western Union could not, and that 119 degrees was one of only a few orbital slot allocations that could be used for such services. In rejecting Western Union's request, but granting a slot at 91 degrees west, the Commission made the following statement:

---

[32] See, Kinsley, Outer Space and Inner Sanctums at 37.

[33] 34 FCC 2d 9, 72-73 (1972).

> [a]t the time of our various orders in Docket No. 16495 it was thought by the Commission that United States domestic satellites could be spaced three degrees apart in the geostationary orbit to prevent mutual interference and that any one of these satellites had to be five degrees from the Anik satellites of Telesat Canada. Based on current system characteristics, and recent calculations made by the system operators, the National Aeronautics and Space Administration and the Commission's staff, it appears that spacings on the order of four degrees will be required between most of the domestic satellites, and the five degree spacing from the Anik satellites will be satisfactory only if certain of the R.F. carriers are not on the same frequency as the susceptible carriers in the Canadian system. Such frequency coordination with Canada, in our view, will be practicable and is justified in the interest of keeping the satellite spacings as small as possible. In the event that smaller earth station antennas should be authorized, wider spacing may be required. . . . For these reasons, satellite spacing of four degrees, starting five degrees from the Anik satellite location of 104 [degrees] west longitude will be used by the Commission as a basis for assigning satellite longitudes in the orbital arc east of the Canadian locations. These spacings are still only a guide. Spacings slightly smaller may be possible in some cases, and larger ones may be required in others, based on actual experience and measurements of satellites as they are manufactured and placed in orbit. Among the uncertainties at this time are the isolation that can be achieved by cross-polarization, the side-lobe levels of earth stations, and the use of small terminals.[35]

In the rush to authorize the launch of a domestic communications satellite system, the Commission had avoided establishing minimum orbital arc spacing. To establish the territory in the domestic communications satellite industry without the formality of a rulemaking proceeding, which would involve considerable time, they quickly determined that 4 degrees would be safe. However, the Commission carefully noted that 4 degrees was simply a guidepost; on October 1, 1981, they adopted a notice of inquiry and proposed rulemaking in docket 81-704 looking toward the most appropriate spacing of the arcs.[36] At this time, the Commission is recommending 2 degrees and may well settle on their original figure, 3 degrees. Some experts argue that anything below 3 degrees may impose a difficult situation on the owners of receive-only antennae.

4. Deregulation of communications common carriers

Parallel with the development of communications satellites, the Federal Communications Commission began to change the structure of common carrier communications regulation, moving toward a more open, competitive marketplace. A detailed discussion of these decisions would be beyond the scope of the task at hand, but it is important to note their existence. The interconnect decisions relating to recording devices, Hush-a-Phone, and Carterfone are important, permitting businesses and individual customers to attach their own telephone equipment to the phone lines.[37] In 1959, the Commission decided to allow private (noncommon carrier) operation in the microwave frequencies.[38] That decision led to the creation of specialized common carriers operating in those frequencies with their own equipment,[39] a development of obvious significance to the satellite proceeding in docket 16495, underway at precisely the same time, since new specialized carriers could operate on their own satellite common carrier frequencies and equipment.

---

[34] 47 FCC 2d 274 (1974).
[35] 47 FCC 2d 274, 275 (1974).
[36] FCC 81-466, 46 Fed. Reg. 57067n (1981).

A related series of decisions in the late 1970's further opened competition. One permitted small communications to contract for lower cost transmission services, such as private leased lines, and then resell or broker them to their own customers. On July 1, 1976, the Commission decided to permit resale and shared use, concluding a 2-year-long proceeding.[40] Translating the impact of the decision to the satellite arena, one may lease a transponder, or a portion of one, and resell or broker some or all of the capacity to others. The most critical of the FCC's common carrier decisions, however is the landmark order in *Computer Inquiry II.*[41] Beginning in 1966, the FCC embarked on a full-scale investigation of the marriage of computer and telecommunications technologies.[42] It was becoming increasingly difficult to draw the line between the highly competitive, unregulated computer industries and the regulated communications industry. Following its inconclusive findings in Computer Inquiry I, the Commission opened a second investigation, Computer Inquiry II. In its initial decision and the reconsiderations, modifications, and amplifications of the past few years, the FCC established a new pattern for the regulation of common carrier communications, one which is not yet fully worked out. Essentially, the Computer II decision divided the world into "basic" communications services and "enhanced" services. Basic services are primarily transmission services—the facilities, frequencies and channel capacity necessary to deliver an electronic message from point A to point B. Enhanced services include everything else, from data processing services to AT&T's Custom Calling and Call Forwarding. Basic services are regulated, enhanced are not, and lines are drawn regarding the business structure through which regulated and unregulated services may be offered. When the line drawing is completed and the transition to Computer II concluded, the business of offering satellite as well as terrestrial communications will be changed profoundly.

---

[37] Docket 6787, 11 FCC 1033 (1947); 20 FCC 391 (1955), affirmed, 238 F. 2d 266 (D.C.Cir., 1956); 250 F. Supp. 188 (N.D. Tex., 1966), 13 FCC 2d 430 (1967), 13 FCC 2d 420 (1968), and 14 FCC 2d 571 (1968).

[38] Allocation of the frequencies above 890 Mc., 27 FCC 359 (1959).

[39] Specialized common carrier services, 29 FCC 2d 870 (1971).

[40] Resale and sharing of private line services, 38 P&F Radio Reg. 2d 141 (1976).

[41] 77 FCC 2d 384 (1980).

[42] Computer inquiry, [illegible] FCC 2d 11 (1966).

D. THE DOMESTIC COMMUNICATIONS SATELLITE FLEET [43]

1. Western Union

After the policy questions had been answered and the Commission's rules implemented in docket 16495, the industry responded with the periodic launching of the spacecraft that comprise the domestic communications satellite fleet. Western Union put up both the first and the second domestic satellites. It launched Westar I on April 13, 1974 and Westar II on October 10, 1974. Both were operating for over 1 year before the next satellite was launched on December 13, 1975 by RCA. Interestingly, Western Union's service on Westar I and II preceded the deregulation of cable television by several years, and their service tends to reflect the demands of the older, more established media.

In December, 1979, American Satellite Corp. [ASC] reached an agreement with Western Union to acquire an ownership interest in the Westar and Advanced Westar domestic communications satellite systems. Under the agreement, ASC, jointly owned by Fairchild Industries, Inc., and Continental Telephone Corp., assumed a 20-percent ownership interest.

WESTAR I

Launch Date: April 13, 1974.

Launch Vehicle: Thor Delta 2914 manufactured by McDonnell Douglas Corp.

Transponders: 12.

Weight: 674 pounds.

Manufacturer: Hughes Aircraft Co.

Location: Until early 1982, this craft served at 99 degrees west longitude which corresponds to Kearney, Nebr. It is now at 79 degrees west which corresponds roughly to Niagra Falls, N.Y.

History and use: Similar to Canada's Anik Satellites. Replaced by Westar IV and most traffic shifted to Westar IV in early 1982. Users include or have included PBS, Muzak, Mutual Broadcast Co., Robert Wold Co., National Public Radio, Dow Jones, RKO Radio, Penthouse, and Paramount Pictures.

WESTAR II

Launch Date: October 10, 1974.

Launch Vehicle: Thor Delta 2914 manufactured by McDonnell Douglas Corp.

Transponders: 12.

Weight: 674 pounds.

Manufacturer: Hughes Aircraft Co.

Location: 123.5 degrees west longitude which corresponds with Mt. Olympus, Wash.

History and Use: This spacecraft tends to be a Western oriented facility. Users include the Independent News Network.

---

[43] Unless otherwise indicated, information about satellite fleet obtained from manufacturer's and carriers.

WESTAR III

Launch Date: August 10, 1979.

Launch Vehicle: Thor Delta manufactured by McDonnell Douglas Corp.

Transponders: 12.

Weight: 674 pounds.

Manufacturer: Hughes Aircraft Co.

Location: 91 degrees west longitude which corresponds roughly to Baton Rouge, La.

History and Use: Because of its location, this facility is easily accessed by users in most points in the continental United States. Users include CBS-Fox, Financial News Network, Spanish International Network, and the Robert Wold Co.

WESTAR IV

Launch Date: February 25, 1982.

Launch Vehicle: Thor Delta 3910 manufactured by McDonnell Douglas Corp.

Transponders: 24.

Weight: 1,290 pounds.

Manufacturer: Hughes Aircraft Co.

Location: 99 degrees west which corresponds to Kearney, Nebr. This spacecraft was tested momentarily at 79 degrees west. It has good access from most points in the continental United States.

History and Use: this craft replaced Westar I which was moved to 79 degrees west. This is Western Union's first 24 transponder spacecraft. Twenty one of these transponders are scheduled to carry full video. Users include Hughes, Bonneville, Westinghouse, Spanish International, American Satellite Corp., PBS, and the Robert Wold Co. Westinghouse plans to move its rights for five of the transponders on this craft to Westar V.

WESTAR V

Launch Date: June 8, 1982.

Launch Vehicle: Probably Thor Delta 3910 manufactured by McDonnell Douglas Corp.

Transponders: 24.

Weight: Probably 1,290 pounds.

Manufacturer: Hughes Aircraft Co.

Location: 123 degrees west which corresponds to Salem, Oreg.

History and Use: Westinghouse plans to program five transponders here with Satellite News Channels. Group W, American Satellites, Dow Jones, and CBS appear to be major subscribers.

WESTAR VI

Launch Date: Proposed December, 1983.

Launch Vehicle: Ariane 3 manufactured by Arianespace (a French company).

Transponders: 24 C Band.

Weight: Possibly about 1,290 pounds.

Manufacturer: Hughes Aircraft Co. (model HS 376)

Location: Not yet assigned.

History and Uses: TSI, Ltd. is reported to have leased two transponders on this craft.

ADVANCED WESTAR

Information regarding this craft is limited. It is intended to be a combination C Band/Ku Band facility, and it could offer unique "spot beam" services as well as a power level higher than that customarily seen in domestic communications satellites. It also is intended to serve as an important component in the Tracking and Data Relay Satellite System (TDRSS) (see chapter nine) that would permit extended communications with satellites orbiting at extremely low altitudes. Location will be at 79 degrees west which corresponds roughly to Niagra Falls, N.Y., and 91 degrees west longitude which roughly corresponds to Baton Rouge, La. The first Advanced Westar was originally scheduled to be launched sometime in 1983. Ownership was planned to be vested in the Space Communications Co., a joint venture between Western Union (50%), Fairchild Industries, Inc. (25%), and Continental Telephone Corp. (25%).[44]

2. RCA American Communications, Inc.

RCA launched its first domestic communications satellite at a time when the cable television industry was being deregulated by the FCC and at a time when Home Box Office was launching its pay television service. RCA offered 24 transponder service on all spacecraft and their ability to carry 24 channels of television programing made them a natural supplier to the new cable industry. The cable operator needed to purchase only one receive-only facility to "see" most of the programing required on his system. This was particularly helpful in 1979 when the receive-only facilities were totally deregulated.

RCA is the only domestic satellite operator that has lost a communications satellite at or near the launching. On December 10, 1979, Satcom III was lost in space as a result of technical failures which occurred while it was being maneuvered into geostationary orbit. It was intended to be a facility totally devoted to cable television, and the ramifications of its loss continue to shake the industry from time to time. The latest problem has been the market-based tariffs that RCA is seeking, and which are more fully discussed in the "Issues" section below.

Because of RCA's commitment to serve Hawaii and Alaska, their satellites tend to be in the western sky. Their only satellite parked at a longitude east of California is Satcom IV.

SATCOM I

Launch Date: December 13, 1975.

Launch Vehicle: Thor Delta manufactured by by McDonnell Douglas Corp.

Transponders: 24 C Band.

---

[44] Fairchild and Continental also hold equal shares of American Satellite Corporation, a communications common carrier that brokers satellite time, and that owns 20 percent of all Westar spacecraft. Because of cost overrums and delays, however, commercial applications may be avoided and NASA may purchase and use the entire facility. Satellite Week, July 5, 1982. p. 1.

Weight: 1,010 pounds.

Manufacturer: RCA.

Location: 135 degrees west which corresponds to Juneau, Alaska.

History and Use: This was the original cable television service satellite. Its users have included Warner Amex, the PTL Club, Dow Jones, United Video (carrying WGN-TV) Cable News Network, Spanish International, Robert Wold Co., Home Box Office, and many others. It tended to be a western service facility however because of its location.

SATCOM II

Launch Date: March 26, 1976.

Launch Vehicle: Thor Delta manufactured by McDonnell Douglas Corp.

Transponders: 24 C Band.

Weight: 1,010 pounds.

Manufacturer: RCA.

Location: 119 degrees west which corresponds to Bakersfield, Calif.

History and Uses: This facility has served Alaska, and such broadcast users as NBC, and the Robert Wold Co.

SATCOM III

Launch Date: December 6, 1979.

Launch Vehicle: Thor Delta 3914 manufactured by McDonnell Douglas Corp.

Transponders: 24 C Band.

Weight: 1,010 pounds.

Manufacturer: RCA.

Location: Would have been located at 132 degrees west which corresponds to a point 20 miles or so west of Ketchikan, Alaska.

History and Use: Due to technical failures, lost in space on December 10, 1979 as it was being maneuvered into geostationary orbit. The loss may have exceeded $77 million. The satellite cost $50 million to build and launch. Some traffic was switched to Comstar D-2 on hasty lease from AT&T at $70,000 per month, per channel. RCA in turn charged $40,000 per month per channel to the customers it moved there. Service on Comstar began about April 1, 1980 for up to ten of the 24 customers on Satcom III.

SATCOM III-R

Launch Date: November 19, 1981.

Launch Vehicle: Thor Delta 3910 manufactured by McDonnell Douglas Corp.

Transponders: 24 C Band.

Weight: 1,260 pounds.

Manufacturer: RCA.

Location: 131 degrees west which corresponds to Prince Rupert in northwest British Columbia or just west of Pitcairn Island in the South Pacific.

History and Use: This craft is often referred to as Cable Net One. It is extensively used for delivery of programming to the cable television industry. Such programming includes Home Box Office, Cable News Network 2, Showtime, ESPN, WTBS, Movie Channel, and C-Span.

SATCOM IV

Launch Date: January 15, 1982.

Launch Vehicle: Thor Delta manufactured by McDonnell Douglas Corp.

Transponders: 24 C Band.

Weight: 1,271 pounds.

Manufacturer: RCA.

Location: 83 degrees west corresponding to Columbus, Ohio.

History and Use: This is Cable Net Two. Eight transponders will go to services interrupted by the loss of Satcom III. Six or eight customers temporarily parked on Comstar D–2 after Satcom III loss could take transponders on this craft. On November 9, 1981, RCA through the auspices of Sotheby, Parke Bernet, the international auction establishment in New York City, auctioned seven transponders on this craft for a combined total of $90.1 million, for an average of $12.87 million each. Some though the price outrageous. Satellite Week suggested that when it only cost $3 million to launch each transponder, this seemed high, particularly when the market might be flooded with transponders soon.[45] In late January, 1982, the FCC rejected the auction results, but suggested that a similar long term leasing approach might pass muster if it were not discriminatory. On March 25, 1982 the Commission consented to a tariff similar to that invited in January. The price authorized was $13 million per transponder. Only three customers responded, suggesting that RCA had discovered the market's limit. Indeed in July 1982, RCA offered to allow customers to reserve a transponder on Satcom 4 for 30 days for a nonrefundable deposit of $150,000.

SATCOM V

Launch Date: Proposed November 1982.

Launch Vehicle: Probably Thor Delta manufactured by McDonnell Douglas Corp.

Transponders: 24 C Band.

Manufacturer: RCA.

Location: 143 degrees west which corresponds roughly to Mt. Blackburn, a 16,390-foot mountain in eastern Alaska.

History and Use: All capacity on this satellite sold to Alascom Inc., a subsidiary of Pacific Power and Light Co. Price set at $180 million or $7.5 million per transponder, roughly half the going rate at the time price agreed to. Apparently the use of this craft will be devoted exclusively to the needs of Alaska and Alaskans.

SATCOM VI

Launch Date: proposed January 1985.

Further information is currently unavailable.

---

[45] Satellite Week, Nov. 9, 1981. p. 6.

3. Comsat General Corp.

In response to guidelines set forth in the Commission's Domestic Satellite proceeding in docket 16495, Comsat created a wholly owned subsidiary intended to launch, own and operate the Comstar series of domestic communications satellites. The entire capacity of these craft has been leased to AT&T and GTE, the two primary telephone companies in the Nation. However, because of Comsat General's participation with IBM and Aetna in the SBS venture (see below), the FCC has determined that this relationship must terminate with the expiration of the Comstar series. It has been estimated that AT&T pays Comsat General about $47 million per year for the use of the Comstar facilities.[46]

COMSTAR D1

Launch date: May 13, 1976.
Launch vehicle: Atlas Centaur.
Transponders: 24 C band.
Weight: 1,787 pounds.
Manufacturer: Hughes Aircraft Co.
Location: 95 degrees west or roughly Leavenworth, Kans.
History and use: Currently colocated with Comstar II, each using half capacity. Both approaching end of useful life. Leased entirely to AT&T and GTE through 1983.

COMSTAR D2

Launch date: July 26, 1976.
Launch vehicle: Atlas Centaur.
Transponders: 24 C band.
Weight: 1,787 pounds.
Manufacturer: Hughes Aircraft Co.
Location: 95 degrees west or approximately Leavenworth, Kans.
History and use: Colocated with Comstar I, each using half capacity. Both approaching end of useful life. Leased entirely to AT&T and GTE through 1983.

COMSTAR D3

Launch date: June 29, 1978.
Launch vehicle: Atlas Centaur.
Transponders: 24 C band.
Weight: 1,787 pounds.
Manufacturer: Hughes Aircraft Co.
Location: 87 degrees west which corresponds to Selma, Ala.
History and use: Leased entirely to AT&T and GTE through 1985.

COMSTAR D4

Launch date: February 21, 1981.
Launch vehicle: Atlas Centaur.
Transponders: 24 C band.
Weight: 1,787 pounds.

---

[46] Wall Street Journal, Apr. 29, 1980, at p. 6.

Manufacturer: Hughes Aircraft Co.

Location: 127.25 degrees west which corresponds to Port McNeill, BC on the northwest tip of Vancouver Island.

History and use: Leased entirely to AT&T and GTE.

4. Satellite Business Systems

Satellite Business System [SBS] is the successor to CML Satellite Corp., the consortium formed between Comsat, MCI, and Lockheed that was mentioned prominently in the Commission's Domestic Satellite proceedings in docket 16495. SBS began with an attempt by International Business Machines Corp. and Comsat General Corp. to form a partnership and create a new, sophisticated business satellite service based on rights to be purchased from MCI and Lockheed. The FCC balked,[47] but suggested that such a plan might work if IBM and Comsat General were to find a third party and assure that the new party have at least a 10-percent ownership interest in the new venture. The Commission also limited the ownership interest of either party to 49 percent or less. Southern Pacific Communications, Western Union International, and many others were both considered and rejected as third parties. In the fall of 1975, Aetna Life & Casualty Co. was selected, and on December 22, 1975, the three parties filed an application under which SBS would operate a comprehensive satellite system providing domestic switched digital service between various points for each private line subscriber. This time, the Commission approved.[48] The Department of Justice, Western Union, and American Satellite Corp. appealed the decision, and lost.[49] Soon thereafter, as indicated below, the SBS satellites began to be launched.

The SBS intention is to establish a U.S. domestic satellite system to provide intracompany communications networks for businesses, Government agencies, and other organizations having large volume communications requirements among dispersed facilities. The networks are fully switchable and provide users with a full range of communications services—voice, high-speed data, high-speed facsimile, and teleconferencing—all in digital format. The marketing emphasis has been on those companies whose telephone expenditures run more than $300,000 per month.

The cost of the entire system is estimated at roughly $500 million. Users include Boeing Computer Services, General Motors Corp., Travelers Corp., Wells Fargo & Co., Westinghouse Electric Corp., and Sears, Roebuck & Co. Service areas could include Canada and Mexico, as well as Britain, France, and others via Intelsat.

This is the first Ku Band domestic communications satellite system. All others had been operating in C Band, that is, downlink at 4 GHz and uplink at 6 GHz. Ku Band uses downlinks at 12 GHz and uplinks at 14 GHz. Smaller facilities can be used on the ground for Ku Band, and some estimate that $1,000 of receive-only equipment in Ku Band will serve as well as $10,000 to $20,000 of equipment in C Band.

---

[47] CML Satellite Corp., 51 FCC 2d 14 (1975).

[48] Satellite Business Systems, 62 FCC 2d 997, 1068, reconsideration denied, 64 FCC 2d 872 (1977).

[49] United States v. Federal Communications Commission, 652 F.2d 72 (D.C. Cir., 1980).

SBS-1

Launch date: November 16, 1980.

Launch vehicle: Thor Delta manufactured by McDonnell Douglas Corp.

Transponders: 10 Ku Band.

Manufacturer: Hughes Aircraft Co. (Model HS-376).

Location: 100 degrees west which corresponds to a line through a point roughly 20 miles west of Abilene, Tex.

History and use: Axial positioning jets operating at only 99 percent thurst. Problem accommodated with modified station-keeping procedures. Other minor technical problems in the receivers and transmitters have been accommodated by backup equipment.

SBS-B

Launch date: September 24, 1981.

Launch vehicle: Thor Delta 3910 manufactured by McDonnell Douglas Corp.

Transponders: 10 Ku Band.

Manufacturer: Hughes Aircraft Co. (Model HS-376).

Location: 97 degrees west which corresponds to the eastern edge of the Dallas International Airport.

History and use: This is the second leg of the SBS system.

5. American Telephone and Telegraph Co.

On December 4, 1980, the Commission authorized AT&T to construct a telstar satellite system consisting of three 24 transponder satellites in C Band and to launch two of the three and place them at 95 degrees west which corresponds with Baytown, an eastern suburb of Houston, and 87 degrees west which corresponds roughly with West Lafayette, Ind. These satellites are to replace the Comstar satellites as they expire. AT&T had been paying roughly $47 million per year to Comsat General for the Comstars, and at that rate, the $230 million investment would pay for itself in just 4.9 years, about half of the useful life of the new facilities. AT&T has contracted with Hughes Aircraft Company for the HS-376 series spacecraft. This is similar to the Westar IV, Hughes Galaxy, and SBS spacecraft. This first satellite is estimated to be launched in April 1983.

6. GTE Satellite Corp.

This is a wholly owned subsidiary of General Telephone & Electronics Corp., and on December 4, 1980, the Commission authorized the company to construct three satellites to operate in the Ku Band (12 and 14 GHz). Authority to launch two of the craft also was granted, and they will be placed at 103 degrees west (a line just east of Rapid City, S. Dak.) and 106 degrees west (a line through Santa Fe, N. Mex.). These craft will be called GSTAR's.

The GSTAR series is intended to compete with SBS, and would therefore seek data, voice, teleconferencing, and image traffic. Shared use transmission facilities are planned; and each craft would have 16 transponders with a useful life of 10 years. This compares with the 10 transponder, 7 year life of SBS. RCA will manufacture the GSTAR's whereas Hughes manufactured the spacecraft for SBS. The GSTAR's are scheduled for launch in the second and third quarters of 1984. The launch vehicle could be the NASA space shuttle, Thor Delta 3920, or the European Ariane 3. Transponder usable bandwidth would be 54 MHz, considerably wider than that offered on SBS (43 MHz). GSTAR's will serve all 50 States.

7. Hughes Communications Inc.

This is a wholly-owned subsidiary of the Hughes Aircraft Co. On December 4, 1980, the Commission authorized it to construct three C Band satellites (4 and 6 GHz). It also authorized the launch of two of them for placement at 74 degrees west (a line roughly through New York City) and 135 degrees west (a line roughly through Sitka, in the lower peninsula of Alaska). These craft have been named "Galaxy." In the spring of 1981, Hughes contracted with Time, Inc. for the sale of six of the transponders on Galaxy 1. Time would use them for distribution of pay television programing by its subsidiary, Home Box Office.[50] The key here is the word "sale." Until then no one had proposed to actually surrender title to transponders on their satellites.

Heretofore, the industry has been the exclusive domain of communications common carriers who leased capacity to users pursuant to a tariff filed at the FCC. Now Hughes proposes to actually sell portions of the facility to users. This has generated a host of novel questions addressed below in the "Issues" section.

The following cable programers have followed suit with purchases of their own transponders on Galaxy 1:

1. Spanish International Network, two transponders.
2. Group W Broadcasting (Westinghouse), four transponders.
3. Times Mirror Satellite Programing, two transponders.
4. Viacom International, two transponders.
5. Turner Broadcasting, two transponders.

This accounts for 18 of the 24 transponders, and Hughes intends to hold six in reserve, rented on a preemptible basis.

In an unusual letter to the FCC early in 1982, Rene Anselmo, President of Spanish International Network, complained to the FCC that Hughes was charging prices on Galaxy 1 that reflected bulk discounts.[51] Mr. Anselmo estimated that the prices on a per-transponder basis were as follows:

1. SIN, $14 million.
2. Group W, $9.5 million.
3. Times Mirror, $14 million.
4. Viacom, $14 million.
5. Turner, $14 million.
6. Time, $8.5 million.

If these numbers were accurate they may raise additional public policy questions. The problem was, since Hughes seems to be selling and not renting, the Commission may have an unusual internal jurisdiction problem. Again, see "Issues" below.

---

[50] Aviation Week & Space Technology, June 15, 1981, at 54.
[51] Broadcasting, Feb. 15, 1982, at 78.

The spacecraft will be a Hughes HS-376, much like Westar IV, SBS, and Telestar.

8. Southern Pacific Communications Co. (SPCC)

This is a wholly owned subsidiary of the Southern Pacific Co. On Dec. 4, 1980, the Commission authorized it to construct three satellites to operate in both C and Ku Bands. The Commission also authorized the company to launch two of them and place them at 70 degrees west (a line through Brunswick, Maine) and 119 degrees west (a line through Bakersfield, Calif.). The service has been named "Spacenet" and the first spacecraft is scheduled for launch in February 1984. The second is scheduled for launch in August, 1984. The first two craft will be launched on the European Ariane. RCA is manufacturing the craft and they will have considerably higher capacity than anything currently planned or authorized in the domestic communications satellite service. At this time, the Spacenet 1 has been heavily contracted for the delivery of video programing. There is a particular emphasis on service to the cable television industry.

9. American Satellite Corp.

This corporation is a joint venture between Fairchild Industries, Inc. and Continental Telephone Corp. It had been a wholly owned subsidiary of Fairchild until the FCC authorized the joint venture on July 17, 1980.[52] American Satellite (ASC) has been a sizable common carrier reseller and broker of satellite services with a heavy investment in the ground facilities required to communicate with satellites. On December 4, 1980, the Commission authorized ASC to acquire a 20-percent interest in all Westar spacecraft from Western Union for $31,900,000. On that day, the Commission also authorized the partners in ASC to join with Western Union to create Space Communications Co. (equal shares to both companies) which would take over all responsibilities and rights from the Western Union Space Communications, Inc. endeavor to launch and operate the TDRSS/Advanced Westar system. ASC will lease half of the usable capacity of this system.

10. United States Satellite Systems Inc.

A recent entrant into the satellite field, it applied in November, 1981 for authority to construct, launch and operate a domestic satellite communications system in Ku band (12/14 GHz) and offer services similar to SBS. The system would be in common carrier format, and the company hopes to launch it in late 1985. The company seeks placement at 88 degrees west (a line through Green Bay, Wis.) and 122 degrees west (a line through San Jose, Calif.). The system would be capable of serving all 50 states.

---

[52] The Washington Star, July 17, 1980, at D7.

E. ISSUES

1. Orbital arcs and the number of communicating spacecraft

In Docket 81-704, the Commission proposed the reduction of the orbital arc from the current four degrees to two degrees.[53] If the Commission finally adopts such a proposal, there could be several important policy problems that arise.

1. Who should shoulder the burden of insuring against increased interference between satellite transmissions and ground systems?
2. Is there one terrestrial industry that is likely to be harmed more than any other? Which one?
3. Is this proposal necessary? Where is the short supply that these new arcs will "cure?" Is it worth that price?
4. Will occasional outbursts of interference from ground communications occur because of the tight spacing?

These and other issues are being explored by the Commission.

When a communications satellite begins to expire, it rarely dies suddenly. Typically it dies bit by bit, transponder by transponder. What would happen if a spacecraft were left in space with only one or two transponders still functioning, particularly if another vendor was prepared to launch a full service spacecraft to replace it? Interestingly, there does not appear to be a mechanism whereby the Commission could easily remedy the problem. If a dying spacecraft were left in space by its owner, even though only one or two of its transponders were still working, it is not clear how the Commission would or could open the slot for another spacecraft before the owner of the original craft had abandoned it.

2. Ariane

The European Space Agency will offer launch facilities from French Guiana located on the northeast shore of South America. It will use the Ariane 3 launch vehicle, and several domestic communications organizations have committed to using it. How should the United States respond to increasing competition from foreign entities in the satellite arena which are generally subsidized? For example, should the United States increase its funding for the space shuttle or rely upon marketplace competition?

3. Research and development by NASA into uses of Ka band

NASA is researching the feasibility of using the 20 to 30 GHz portion of the spectrum, also known as the Ka band. Should these expenditures be undertaken by government or should the private sector pay the research and development costs, particularly when it might be the primary beneficiary? If the Department of Defense is a major user of the technology, should it therefore contribute significant funding for its development?

4. Spacecraft ownership

As noted above, Hughes Communications is preparing to launch Galaxy 1, the condominium spacecraft where users of the craft actually "own" their transponders. This is the first proposal of this sort. The Commission rejected RCA's auction of transponders on Satcom IV, but later authorized a market-based tariff. Such schemes call into question the common carrier premise on which today's domestic communications satellite regulation is based. It also points up the need for an examination of the existing management structure at the Commission. Should there be a Satellite Bureau that covers all aspects concerning satellites, from engineering to private ownership to common carriage? Also, should there be ownership rights granted to the orbital slots themselves?

---

[53] 46 Fed. Reg. 57067 (Nov. 11, 1981).

5. Copyright

It is unclear how satellite communications might violate the Copyright Act, but this could change to the extent satellite communications are deemed not to be common carriage. Then the relay might be deemed to be a "performance" under certain circumstances protected by the Copyright Act, 17 U.S.C. 88, 101 et. seq. In a recent judicial case, a cable operator stripped the information off the vertical blanking interval of a television broadcast signal before relaying it by satellite from Illinois to New Mexico. Did that conduct remove the cable operator from the exemption granted common carriers to protect them under section 111(c)(3) the Copyright Act? That question is in litigation.[54] Does a common carrier's selection of the programing it will transmit, such as when it selects a televison broadcast signal because it carries many of the games played by a specific sports team, render it something other than a common carrier, protected under section 111(c)(3) of the Copyright Act? This question too is in litigation.[55] These are actual examples of the many copyright issues that may require attention.

6. Access

Satellites cannot work alone. They require a fabric of terrestrial links and interlinks through which to relay their programing. The satellites have been discussed above. Under the present FCC policy, receive-only Earth stations are subject to optional regulation. However, the uplinks and the service to the uplinks can be restricted by preexisting users of the same frequency, particularly in congested areas such as Washington, D.C. Some of the access restrictions are certainly undertandable. The satellite frequencies are shared with microwave services on the ground and increased use of terrestrial microwave has created a spectrum congestion issue for the Commission. Two areas seem particularly vulnerable, the uplinks and the microwave paths to them. If one or the other suffers from congestion satellite services will be difficult or impossible to operate.

How can the Commission ensure that terrestrial abuses don't occur which might restrict access to satellites?

---

[54] The Seventh Circuit Court of Appeals decided that it did, see *WGN* v. *United Video*, No. 81-2687 (Aug. 11, 1982).

[55] A New York district court found the statutory exception does not apply where the carrier independently selects the signal to carry and sell, see *Eastern Microwaves, Inc.* v. *Doubleday. Sports, Inc.* 534 F. Supp. 533 (N.D.N.Y. 1982), appeal pending before the Second Circuit Court of Appeals.

7. International

International issues are likely to result from either the scarcity of frequencies and orbital slots, or from the unlimited number of received points possible and distance traversed. The various regional and world adminstrative radio conferences held under the auspices of the International Telecommunication Union deal with these problems on a long-term basis. There may also be a potential for foreign broadcast programing to be delivered to audiences in the United States. Such programing might include a biased rendition of controversial issues of public importance or it could contain personal attacks on American public figures. The U.S. Government's response to such programing may raise fundamental first amendment issues. Other international issues, including the need for satellite services and expertise in the developing countries and the authorization of transboarder satellite services using domestic satellites are discussed in section III of this chapter.

8. Theft of service and privacy protection

Theft of service and privacy protection will continue to challenge both the users of satellites and the Government. The problem may be exacerbated by increased delivery of intrinsically valuable information such as the electronic transfer of funds through satellite signals which can be received at an infinite number of points. The present protections against divulgence and use provided by section 605 of the Communication Act might be inadequate to prevent such problems.

9. Intentional destruction of satellites

The technological genius that brought us communications satellites is cabable of bringing us the means by which to sabotage or destroy these fragile craft. The loss of Satcom III has demonstrated the possible impact of such a loss. Litigation over that loss continues to proceed. Should destruction occur, terrestrial facilities would be required on short notice to carry the satellite traffic. Should the terrestrial carriers be required to hold capacity in strategic reserve? Who should pay for maintaining this capacity? Would the Commission permit rates calculated to hold such channels in reserve?

10. Cross-subsidization

As the terrestrial carriers such as AT&T and GTE extend their services by using domestic satellites that they own, cross-subsidization of services becomes a possibility. The Commission has addressed issues concerning cross-subsidization between monopoly and competitive services by such carriers in its Computer II decision discussed above. Similarly cross-subsization issues have been focused on in major legislative efforts to rewrite the Communications Act of 1934.

11. Transponder glut

By 1985, there could be over 600 transponders available or in use on the domestic communications satellite fleet, compared to approximately 200 in 1982. If the demand for these transponders that is expected from teleconferencing and other new uses does not materialize, there could be a glut. Industry analysis do not agree whether such a situation might occur or not. Some studies show that the increased demand will be more than adequate to utilize the number of transponders. Others show the opposite. For example, in June 1982, the FCC found 81 transponders (41 percent of total) not in use during the midday hours in the eastern daylight time zone. In addition, as noted previously, RCA changed its policy to allow customers to reserve transponders on Satcom 4 for 30 days for a nonrefundable deposit of $150,000 pending a final decision. How would such a glut be financed? Would the users of transponders have to pay for unused transponders? Would the carrier bear the financial burden? Should the Commission continue to authorize the construction and launch of these facilities should a glut materialize?

12. Ownership

As noted in the section on Hughes Communications and RCA's Satcom IV, there is significant interest by vendors and users alike in permanent property rights to use satellites. Users wish to own and vendors wish to sell rights to use these spacecraft, much like the condominum scheme in real property. This might frustrate the existing regulatory framework which is based on common carriage. Unlike broadcast, cable, and private radio, the Commission has not promulgated a regulatory scheme to manage private ownership of transponders. Furthermore, it is not clear that the Communications Act offers the required flexibility. The Commission has issued a Notice of Proposed Rulemaking in Domestic Fixed Satellite Transponder Sales hoping to resolve these and many other questions.[56] Eventually, the sale of the orbital slots to the vendors may also be considered.

13. Anticompetitive conduct

Despite the free and open nature of the domestic satellite industry, anticompetitive abuse remains a possibility. Use of ground facilities can be bound to the use of transponders with the argument that quality of service can only be assured if the vendor controls the entire system. In such a situation, pricing can be predatory and the equipment and services offered by competitors potentially barred. What safeguards are needed to prevent such activities?

14. Environmental protection

The proliferation of satellite communications facilities could threaten existing environments. This may be of particular concern in regard to large uplink facilities and the facilities that might be required if the orbital arcs are reduced to 2 degrees as proposed by the Commission. Another aspect of this is the possibility of hazardous radiation levels from high powered transmissions.

---

[56] Notice of Proposed Rulemaking in Common Carrier Docket 82-45, 47 Fed. Reg. 6446 (released Feb. 8, 1982).

15. Land-mobile satellite service

There is considerable evidence that a Land-Mobile Satellite Service could promote mobile telecommunications use (radio transceivers in cars, boats, trains, trucks, planes, etc.). This is already being done with considerable success in the maritime industry where satellite navigation systems communicate through small vertical whip antennae on the ships. NASA recently requested the FCC to start a rulemaking to reserve spectrum for this type of service. What might the impact of such a new satellite service be?

F. CONCLUSION

Domestic satellite communications is still in its infancy. Up to this time the Commission has promoted flexibility as it deals with the novel questions presented by this emerging technology. As the industry matures and enters its second generation of spacecraft, however, there could arise instances where more specific congressional guidance might be sought. The issues outlined above describe the breadth of possible concerns. Most do not appear to demand immediate congressional attention. However, several issues such as orbital spacing and ownership rights relating to both the orbital slot and the individual transponder may come before Congress if there is strong dissent to the FCC's resolution of these issues in proceedings which are currently underway.

X. DIRECT BROADCAST SATELLITES [DBS] [57]

A. INTRODUCTION

Direct broadcast satellites [DBS] have moved from being a promising concept to the point where a number of DBS systems will become operational in the next several years. Advances in satellite technology combined with a favorable regulatory environment and substantial commercial interest provide the basis for this development. What makes direct broadcast satellites unique and also causes much of the controversy is their ability to transmit signals directly to receiver antennas which are both small and inexpensive enough for individual homeowners to install without retransmission via local broadcasting facilities. The result is that high quality television signals can be beamed directly into any region or country regardless of what terrestrial network exists. Although direct broadcasting satellites have been heralded as a significant new communications capability, their introduction has caused much debate both within the Government and the private sector. This section will provide an overview of the development of DBS technology, give a chronology of the actions taken by the Federal Communications Commission to open up this new service, identify existing proposals for DBS systems, highlight international DBS activities, review congressional interest, and address the major issues involved in implementing direct broadcast satellite systems.

---

[57] Information in this section is current as of Mar. 1, 1983.

1. Early history

Direct broadcast satellite systems are defined as satellites which relay signals intended for reception by the general public. These signals may be received either by community antennas for further distribution or directly by individuals.[58] They were first successfully tested when the National Aeronautics and Space Administration [NASA] launched the ATS-6 satellite in 1974. Placed in geostationary orbit, ATS-6 was capable of broadcasting television signals directly to community receivers. The DBS system carried in the ATS-6 payload was used for several projects. One experiment provided television programing to educational institutions in the United States, another involved a joint United States-India effort, and a third was used for demonstration projects in Africa [AIDSAT].[59]

In the case of the joint United States-India project the United States loaned the ATS-6 satellite to India for 1 year beginning in August 1975 for its Satellite Instructional Television Experiment [SITE]. The satellite was used for broadcasting instructional programing directly to nearly 2,400 villages. In addition, another 2,600 ground terminals received instructional programing from ATS-6 and rebroadcast it to numerous villages and cities nearby. It is estimated that the program reached 5 million people in India. The programing was aimed at several different audiences, including the general adult population, schoolchildren, teachers, and other technical staff requiring specialized training.[60] The success of the program prompted the Indian Government to pursue development of their own direct broadcast satellite capability.

Other DBS experiments have been conducted by several countries, including Canada, Japan, and some European nations. The Communications Technology Satellite [CTS], placed into geostationary orbit in 1976, was developed jointly by the United States and Canada and operated in the 12/14 GHz band. Canada designed and built the satellite, while the United States provided the 200-watt traveling wave tube transmitter and launch facilities. The CTS effort advanced the technical feasibility of high-powered satellites and their component spacecraft and ground antenna parts. At the same time the satellite was used to demonstrate the feasibility of improving education, health care, and community services in remote areas through the use of high-powered, communications satellites.[61] Efforts, such as ATS-6 and CTS were critical for testing and advancing the technologies associated with direct broadcasting satellites and for demonstrating the utility of transmitting television programing to areas unserved by more conventional communications means. Although DBS systems are generally viewed as providers of television programing, they can also be employed for various types of data transmissions.

---

[58] Pattan, B. Technical Aspects Related to Direct Broadcasting Satellite Systems. Office of Science and Technology. Research and Analysis Division, Federal Communications Commission, September 1980. pp.1-2.

[59] See Chapter VI for a detailed description of the ATS-6 program.

[60] Ibid.

[61] NASA News. Communications Technology Satellite. Release No. 75-316. Jan. 11, 1976.

2. The technology

A number of technological factors are involved in making direct broadcast satellites both feasible and economically viable. DBS systems combine high power satellites providing multiple channels for home reception and small, inexpensive individual receivers capable of receiving multiple channels. In essence, the concept behind direct broadcasting systems is to increase the power of the space segment so that the ground segment can be less costly and cumbersome.

Direct broadcast satellites require large sources of primary power, the ability to generate high power efficiently, some method for dissipating the heat generated by a high power system, and antennas with shaped beams capable of contouring a specific geographic area. A number of advances have been made in: traveling wave tube technology which increase the efficient use of power, lightweight solar paddles for increasing primary power, the use of higher frequencies in the radio spectrum, improved satellite attitude and orbit control, and solid state components, including new materials—all of which contribute to the viability of DBS systems.[62] The difference between a typical domestic communications satellite and a direct broadcast satellite can be illustrated by comparing RCA's Satcom V and its proposal for a DBS satellite.[63] (See figure (3.)

---

[62] Briefing by B. Pattan, Federal Communications Commission, Feb., 1983.

[63] Ibid.

FIGURE 3-3.—TYPICAL DBS SYSTEM

COMPARISON BETWEEN A DOMSAT AND DBS SATELLITE

PARAMETER	SATCOM V	DBS SAT. (RCA)
COVERAGE	U.S.	TIME ZONE SIZE
SAT. TYPES	3-AXIS STAB.	3-AXIS STAB.
SOLAR ARRAY SIZE	39 FEET	75 FEET
WT IN ORBIT	1000 LBS	1900 LBS
D.C. POWER (EOL)	1000 W	3500 W
NO. OF XPDRS	24	6
XMTR POWER	8.5 W (S.S.) [η=33%]*	230 W (TUBE) [η=50%]
EIRP (CH)	35 dBW (CONUS)	58 dBW (EOC)

* TWTA EFF.:=37%

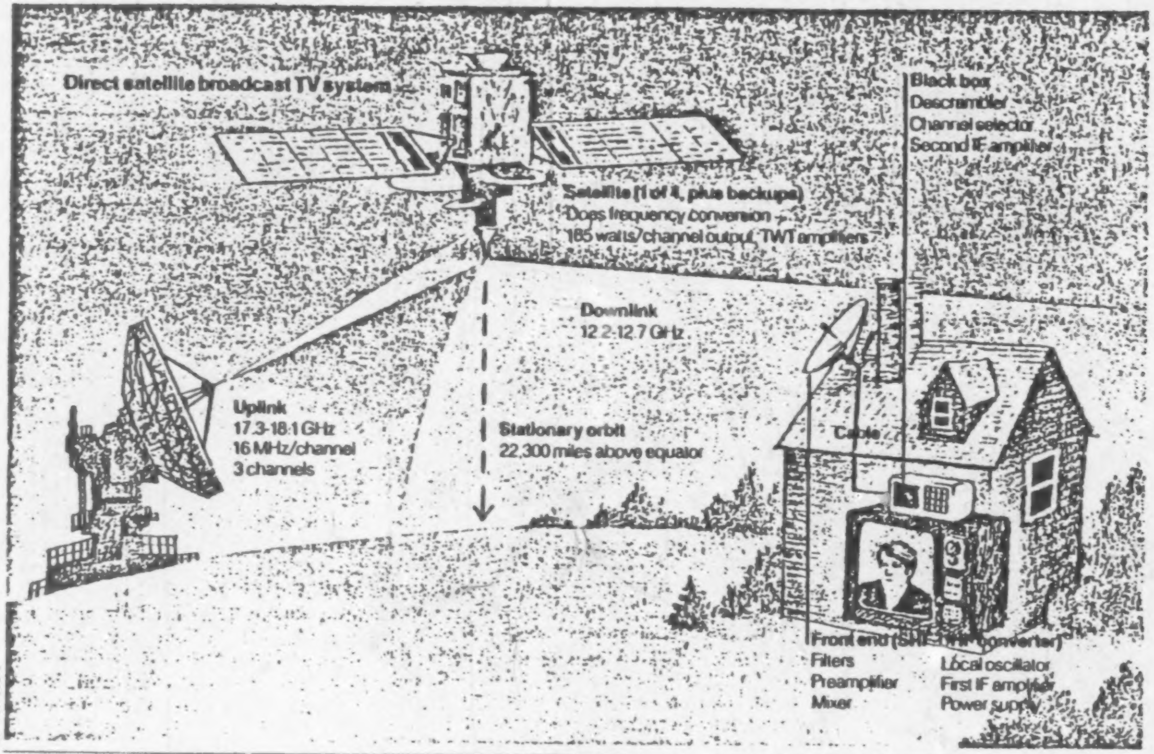
Similarly, considerable improvements being made in ground receiver systems enhance the potential for effective DBS systems at reasonable costs. Basically, what the receiver must do is to convert the 12 GHz signal from the satellite "into an intermediate frequency [IF] for further processing in a small box atop the viewer's TV set. This box will perform further IF amplification, channel selection, and unscrambling of coded transmissions, delivering a high quality TV signal to the set it feeds."[64] Of critical importance is the need for these receivers—approximately 2½ feet in diameter—to be mass produced at a reasonable cost. While estimates vary, figures between $150 and $700 have been offered by various companies as likely prices for receivers, once full-scale production is achieved. It is hoped that recent advances in receiver technology and the potential of offset feed antennas will provide increased performance of receiver antennas while maintaining low costs. The graphic example of a typical DBS system below illustrates the interrelationship between the component Earth and space segments.[65] (See figure 4.)

---

[64] Fawcette, James. "Direct Satellite TV: The 12-GHz Challenge." High Technology, January/February 1982. p. 43.

[65] Ibid.

FIGURE 3–4


Direct satellite broadcast TV system
Satellite (1 of 4, plus backups)
Does frequency conversion
185 watts/channel output, TWT amplifiers
Black box
Descrambler
Channel selector
Second IF amplifier
Downlink
12.2-12.7 GHz
Uplink
17.3-18.1 GHz
16 MHz/channel
3 channels
Stationary orbit
22,300 miles above equator
Cable
Front end (SHF-UHF converter)
Filters
Preamplifier
Mixer
Local oscillator
First IF amplifier
Power supply

B. Federal Communications Commission [FCC] Actions

1. Staff reports

The Federal Communications Commission [FCC] focused increased attention on the issue of direct broadcast satellites in recent years as the technology improved and commercial interest grew. For example, in 1980, both as part of its network inquiry into the practices of the television industry and as a followup to the 1979 World Administrative Radio Conference [WARC], the FCC issued two reports on direct broadcast satellites. In March 1980, the FCC's Network Inquiry Special Staff issued its "Preliminary Report on the Prospects for Additional Networks" which included a section on the legal and policy options for direct broadcasting satellites.[66] The report foresaw DBS systems as a viable alternative to existing television programing and identified alternative approaches for regulating this new service.

In September 1980, the staff of the FCC's Office of Plans and Policies issued its report, "Policies for Regulation of Direct Broadcast Satellites." The report concluded that "in establishing a regulatory scheme for DBS . . . most forms of regulation now imposed by the Commission will prove unnecessary or counterproductive." [67] The staff report found that competition among various DBS service providers would provide sufficient incentive for serving consumers at the lowest prices, thereby making additional regulatory measures—other than spectrum allocation and assignment of frequencies—unnecessary.[68] In addition, the FCC's Office of Science and Technology issued a report in September 1980 entitled Technical Aspects Related to Direct Broadcasting Satellite Systems.[69]

2. Relevant FCC dockets

In 1980 the Federal Communications Commission opened two dockets specifically concerning direct broadcast satellites. As part of the preparation for the 1983 Region 2 Administrative Radio Conference of the International Telecommunications Union [ITU] for the planning of broadcasting satellite service, the FCC initiated general docket No. 80-398 to request comments from the public. The first notice of inquiry was released on July 25, 1980 and sought public response to a number of issues involved in developing the position of the United States for the 1983 Region 2 Conference. These issues were stated as:[70]

> (1) Basic Service Requirements of each of the administrations of the Region; (2) Technical Specifications and Sharing Criteria that must be established in order to draw up an effective plan; and (3) Planning Principles and Procedures, which must be established to provide guidance for the plan and the implementation and future modifications or additions thereto.

---

[66] Federal Communications Commission. Network Inquiry Special Staff. Preliminary report on Prospects for Additional Networks. Washington, D.C., March 1980.

[67] Federal Communications Commission. Office of Plans and Policies. Policies for Regulation of Direct Broadcast Satellites. Washington, D.C., September 1980, p. 87.

[68] Ibid., pp. 88-89.

[69] Pattan, B. op. cit.

[70] An inquiry relating to preparations for the 1983 Region 2 Administrative Radio Conference of the International Telecommunications Union for the planning of the broadcasting-satellite service in the 12 GHz band and the associated uplinks, notice of inquiry, 45 Federal Register 51914 (Aug. 5, 1980).

Included in these issues are such items as the type of service to be offered, the number of service areas, the number of channels and channel spacing, satellite orbital positions, how the frequency band 12.1 to 12.3 GHz should be divided between broadcasting and fixed services, interference protection, equipment characteristics, and the general planning approach which should be pursued. Subsequently, additional Notices of Inquiry were issued, a joint industry/government advisory committee has met regularly, and staff have been preparing positions for consideration by the FCC Commissioners. It is expected that the FCC will announce its proposals for the 1983 Region 2 Conference in March 1983.

A second major docket (general docket No. 80-603) was opened in 1980 to identify the appropriate regulatory policy for direct broadcast satellites following the conclusion of the 1983 Region 2 Conference on broadcasting satellites. A Notice of Inquiry was released by the Commission on October 29, 1980 which sought to begin the process to establish a regulatory policy for DBS "to ensure that it serves the public interest." [71] To accomplish that the FCC stated that three goals should be pursued:[72]

> Efficient use of the spectrum (including the balance between DBS and other services), opening new channels to allow an opportunity for diversity of voices in order to further the goals of the First Amendment, and satisfaction of consumers' preferences for programing.

The Notice of Inquiry [NOI] requested public comments on the market for video programing, spectrum allocation and assignment methods, technology and technical standards, questions of cross-ownership and control, program content, and appropriate regulatory classification options. Furthermore, the NOI asked for comments on whether interim DBS services should be authorized prior to the 1983 Region 2 Conference and if so, under what constraints.

On April 21, 1981 the FCC adopted a Notice of Proposed Policy Statement and Rulemaking (FCC 81-181) which recommended conditions for authorizing experimental DBS services prior to the 1983 Regional Administrative Radio Conference (RARC). The Notice found that, despite opposition to this new service from the broadcasting industry, DBS would serve the public interest and "would not conflict with the Commission's longstanding commitment to local broadcasting." [73] In addition, the Commission stated that although permanent regulatory policies could not be established until after RARC-83, approval of interim services would have the advantages of avoiding delays in initiating DBS systems and in bolstering the U.S. negotiating position at the RARC-83 Conference. At the same time, the Commission sought to maintain the greatest degree of flexibility possible to avoid potential conflicts with the final outcome of RARC-83. Finally, the notice stated that the FCC would accept applications for interim DBS services, thereby opening up for consideration the application the FCC had already received from Satellite Television Corporation [STC], a subsidiary of the Communications Satellite Corp. [Comsat].

---

[71] Inquiry into the development of regulatory policy in regard to direct broadcast satellites for the period following the 1983 regional administrative radio conference, notice of inquiry, 45 Federal Register 72719 (Nov. 3, 1980).

[72] Ibid.

[73] Inquiry into the development of regulatory policy in regard to direct broadcast satellites for the period following the 1983 regional administrative radio conference, notice of proposed policy statement and rulemaking, 46 Federal Register 30124 (June 5, 1981).

After another series of public comments, the Federal Communications Commission unanimously adopted a report and order (FCC 82-285) on June 23, 1982 setting "interim" rules for direct broadcast satellite services. Among the major findings of the report are the following: [74]

> Authorization of DBS service in the 12.2-12.7 GHz band would serve the public interest because it would benefit remote areas, provide additional channels of programing, promote innovative services, and be more responsive to viewer's preference.
>
> Authorization of interim DBS service will allow for implementation of service earlier than if the United States waited until after the RARC Conference and that definite proposals will assist in formulating the U.S. position for the Conference.
>
> DBS services would not have a significant impact on the audiences, revenues, or programing of local broadcasters.
>
> Existing terrestrial users will need to be relocated to other bands to avoid interference with DBS services. However, by establishing a transition period when DBS and fixed service [FS] users of the 12 GHz band will have coequal status will minimize the cost to existing terrestrial users of relocating.
>
> A spectrum allocation of 500 MHz is needed to satisfy present and anticipated demand for DBS services. DBS downlinks should operate in the 12.2-12.7 GHz band, while uplinks should operate in the 17.3-17.8 GHz band.
>
> Construction permits will be granted for 5 years with construction to begin within 1 year after approval of an application by the FCC. The satellite must be in operation within 6 years of the granting of the construction permit.
>
> A flexible regulatory approach for DBS is in the public interest. Minimum regulations and technical standards to conform with international agreements and U.S. statutes should be all that are established.
>
> DBS systems will be classified according to the type of operation and services offered (e.g. broadcasters, common carrier, hybrid) rather than under a single regulatory classification.
>
> The DBS allocation may be used for either high definition television transmissions or for conventional television signals.

3. DBS applications

The FCC's April 1981 Notice of Proposed Rulemaking opened up the field for direct broadcast satellite services by accepting the application of Comsat's Satellite Television Corporation [STC] and inviting others to submit proposals. By the July 16, 1981 deadline, 12 additional applications had been received. The number of proposals was larger than many expected and therefore caused some concern that more orbital slots may be needed than the United States may receive at the RARC-83 Conference. At the same time, however, the broad range of proposals appeared to achieve the FCC's goal of introducing a variety of alternatives for the viewing public.

---

[74] Inquiry into the development of regulatory policy in regard to direct broadcast satellites for the period following the 1983 regional administrative radio conference, report and order, 47 Federal Register 31555 (July 21, 1982).

In some instances the applicant proposes to offer subscriber-supported services; in others it will be advertiser supported. A few applicants want to be strictly common carriers for DBS programing, while most want to provide programing as well. In addition to purely video programing, some applicants also proposed to carry other services such as data transmission and videotext as well. One applicant proposed that its DBS system be used for transmission of high definition television. Differences in type of ownership and targeted audiences also varied among the applicants. Applicants were permitted to request the form of regulation they desired dependent upon the type of service they planned to offer. Requests varied from common carrier status, to private carrier, to broadcaster, to hybrid offering.

On September 23, 1982, Comsat received approval from the Federal Communications Commission to begin building the first phase of its direct broadcast satellite service, Satellite Television Corporation [STC]. On November 5, 1982, the FCC approved seven additional applications to construct DBS systems. Like the approval for STC, these permits are contingent upon the outcome of the RARC scheduled for June 1983. Key elements describing the systems of the eight approved applicants appear in the following charts.[75] The companies which received FCC approval include: CBS, Direct Broadcast Satellite Co., Graphic Scanning Corp., RCA Americom, United States Satellite Broadcasting (Hubbard), Video Satellite Systems, and Western Union. Qualifications were added to a few of the permits. CBS was asked to provide additional cost projections for its plans for a high definition television system, while Graphic Scanning Corp.'s approval is contingent upon the outcome of another FCC proceeding in which questions were raised about possible company improprieties.[76] Five additional applications are currently pending at the FCC.

A related development is the proposal for so-called "lower-power" or "interim" DBS systems. Employing fixed communications satellites operating in the 11.7-12.2 GHz band, programing can be transmitted to ground antennas, which although larger and more expensive than those anticipated for high power DBS systems, are smaller and cost substantially less than equipment needed to operate with satellites located in the 4-6 GHz band. United Satellite Communications, Inc. (USC)—formerly United Satellite Television Corp.—is planning such a service using transponders leased by GTE Satellite Corporation on Canada's Anik C-2 satellite, scheduled for launch in May 1983, and subsequently switching to GTE's own fixed satellite [GSTAR A-1] when it is launched in 1984.[77] Recently, Prudential Insurance Co. of America announced that it was investing $45 million in USC.[78]

---

[75] Data accumulated from numerous sources, including material provided by the applicants and news summaries of the applications.

[76] "Where There Once Was One, There Now Are Many." Broadcasting magazine. Nov. 8, 1982. p. 40-41.

[77] "Prudential Places a Bet on DBS." Broadcasting magazine. Feb. 7, 1983. v. 104. no. 6. p. 31.

[78] Ibid.

By initating this type of satellite broadcasting service with five channels of programing, USC hopes to capture a large share of the market which is currently not served by cable several years before any of the high powered DBS systems become operational. The FCC approved GTE Satellite Corp's application for the lease of ten transponders from Telesat Canada in August 1982, however, the FCC subsequently received several objections to the decision and a reconsideration of the matter is pending as of March 1, 1983.

COLUMBIA BROADCASTING SYSTEM [CBS]

Satellites: Four in orbit, plus two spares.

Channels: Three.

Bandwidth: Two channels of 24 MHz needed for transmission of high definition TV.

Orbital slots (degrees west longitude): Not available.

Weight: 989 kg., and 1,053 kg.

Cost: $140 million for initial phase.

Coverage: Four time zones.

Services: CBS asked to be regulated as a hybrid, offering a range of services. It would provide for retransmission by local CBS–TV affiliates and cable operators, satellite-to-theater movie distribution, and home and business subscription programming. All channels would deliver high definition television with stereophonic sound.

DIRECT BROADCAST SATELLITE CORP. [DBSC]

Satellites: Three orbit, plus one spare.

Channels: Six primary (30 to 42 possible with spot beams in full operation).

Bandwidth: 22.5 MHz.

Orbital slots (degrees west longitude): 103, 123, 143.

Weight: 1,358 kg.

Cost: $577 to $614 million.

Coverage: Three time zones, four spot beams.

Services: DBSC proposed to offer many more channels than any other satellite system; it claimed that this is feasible with current technology. DBSC hopes to lease channels as a common carrier.

GRAPHIC SCANNING

Satellites: Two in orbit, plus one spare.

Channels: Two.

Bandwidth: 18 MHz.

Orbital slots (degrees west longitude): 115, 143.

Weight: Not available.

Cost: Not available.

Coverage: Two one-half conus beams plus spots to Alaska, Hawaii, Puerto Rico, and the Virgin Islands.

Services: Graphic Scanning hopes to broadcast subscription TV including closed caption entertainment, as well as electronic text services to subscribers. Each satellite would be independently programmed.

RCA AMERICOM

Satellites: Four in orbit, plus two spares.
Channels: Six.
Bandwidth: 24 MHz (72 MHz for high definition TV).
Orbital slots (degrees west longitude): 95, 170.
Weight: 1,106 kg.
Cost: $760 million.
Coverage: Four U.S. time zones, Alaska and Hawaii.
Services: RCA proposed to both lease channels and broadcast directly to home and business. The company also plans to offer stereophonic sound and high definition television.

SATELLITE TELEVISION CORP. (STC)

Satellites: Four in orbit, plus two spares.
Channels: Three.
Bandwidth: 16 MHz.
Orbital slots (degrees west longitude): 115, 135, 155, 175.
Weight: 650 kg.
Cost: $700 million for initial phase covering Eastern time zone.
Coverage: Four time zones.
Services: STC would broadcast entertainment programming directly to subscribers. It would also offer electronic textual services to homes and businesses. Other enhancements include stereophonic sound, closed captioning, and programming in Spanish.

UNITED STATES SATELLITE BROADCASTING (HUBBARD)

Satellites: Two in orbit, plus one spare.
Channels: Three.
Bandwidth: 16 MHz.
Orbital slots (degrees west longitude): 115, 135.
Weight: 1,045 kg.
Cost: $300 to $400 million.
Coverage: Four time zones (two on each satellite).
Services: USSB hopes to broadcast entertainment directly to homes and businesses, and provide retransmission by terrestrial broadcasters. Other features include stereophonic sound and high definition television.

VIDEO SATELLITE SYSTEMS (VSS)

Satellites: Four in orbit, plus one spare.
Channels: Two.
Bandwidth: 17.5.
Orbital slots (degrees west longitude): 115, 135, 155, 175.
Weight: 546 kg.
Cost: $228 to $23 million.
Coverage: Four time zones, and spot beams.
Services: This system would carry the Dominion Satellite Network's programing to homes and businesses and would be supported by advertising. Programing would also be distributed by terrestrial broadcasters.

WESTERN UNION

Satellites: Four in orbit, plus two spares.
Channels: Four.
Bandwidth: 18.
Orbital slots (degrees west longitude): 80, 100, 120, 140.
Weight: 534 kg.
Cost: $450 million.
Coverage: Four time zones, Alaska, Hawaii, Virgin Islands.
Services: Western Union asked to be regulated as a private, or discriminatory, carrier which would lease channels to selected customers.

C. INTERNATIONAL ACTIVITIES

1. DBS efforts in other nations

Numerous countries around the world are studying the feasibility of initiating direct broadcast satellite services and several are already in the development stage. Among these countries are Sweden, Luxembourg, France, Germany Switzerland, India, Canada, the United Kingdom, and Japan. In addition, regional capabilities for Scandinavia and Europe are anticipated. In some instances, such as Canada, an interim system employing the low power Anik C spacecraft is already operational utilizing community receivers. In others, plans call for development of higher power satellite systems capable of transmitting information to smaller ground terminals (approximately 3 feet in diameter) located at individual homes.

A substantial amount of DBS activity is occurring in Europe, for example. A French-German team anticipates launching the first DBS satellite system in Europe in 1984, using the European Space Agency's Ariane 3 rocket. Two satellites will be launched—one for France, [TDF-1], and one for Germany, [TV-Sat]. Each is expected to have a three-channel capacity and both countries plan to use two channels to deliver programing for their national television stations. In 1985, two additional satellites will be launched providing increased channel capacity and a fully operational system with spare satellites in orbit.[79]

The European Space Agency [ESA] likewise has been involved in developing satellite television capabilities. In July 1979, 10 of the ESA member countries adopted a resolution proposing the L-Sat (large satellite) program. The United Kingdom made the largest investment in L-Sat, but contributions were received as well by Holland, Italy, Switzerland, Denmark, Belgium, and Spain. Although L-Sat will be used for a variety of telecommunications purposes, Italy has already announced its desire to use the satellite for direct broadcasting of television programing.[80]

Another focal point of DBS activity in Europe is Luxembourg. Radio-Tele-Luxembourg, owned by Companie Luxembourgeoisie de Telediffusion [CLT], is currently the largest commercial broadcaster in Europe. Initial plans call for launch of Luxsat by the mid-1980's with programing offered in French, German, and either English or Dutch.[81] Luxembourg is anxious to develop a DBS capability particularly in light of its location in Europe. The footprint from a Luxembourg satellite would cover France, Germany, Switzerland, and Holland and provide for an extensive audience.[82] The proposal for Luxsat may run into considerable difficulty, however, from neighboring European countries where television networks are state owned. Countries such as Germany and France fear that commercial broadcasting from satellite could affect adversely their existing government-controlled stations, and could contravene regulations covering programing and advertising.[83] At present, the European Parliament is addressing the issue of direct satellite broadcasting and possible European-wide agreement on programing and advertising guidelines.[84]

---

[79] Hewish, Mark. "Satellite Television Improves the View." New Scientist, Feb. 12, 1981. p. 401.

[80] Matte, Nicholas Mateesco. "Aerospace Law: Telecommunications Satellites." Butterworth & Co. p. 182.

2. U.N. consideration of DBS

The United Nations first raised the issue of broadcasting radio and television programing from satellites directly to the general public nearly two decades ago. During this timeframe numerous proposals for establishing principles governing DBS were advanced and extensive debate on the topic occurred in a number of U.N. forums.

In 1968 the U.N. General Assembly passed a resolution to establish a working group on direct broadcast satellites within the Committee on the Peaceful Uses of Outer Space [COPUOS]. The committee was charged with studying the technical developments in DBS, cost factors involved, and the social cultural, and legal implications of direct broadcast satellite systems.[85]

Actions in UNESCO concerning communications issues also added impetus to the debate on DBS. In 1972 a Unesco communications committee draft declaration included language stating that:[86]

> It is necessary that states, taking into account the principle of information, reach or promote prior agreements concerning direct satellite broadcasting to * * * countries other than the country of origin of the transmission.

Later that year, despite strong opposition by the United States, the Unesco General Conference approved a "Delcaration of Guiding Priniciples on Satellite Broadcasting" which followed the report submitted by the communications committee.[87]

Also in 1972, the General Assembly recommended that COPUOS draft recommended principles to regulate the use of direct broadcast satellites. After a series of meetings a first set of draft principles was produced in 1974. These principles became the basis of further discussion and debate over the remaining areas of controversy. Several major proposals were offered by different countries reflecting their respective positions on the issue.

---

[81] Newman, Barry. "European States Face Problem of Controlling Their Neighbor's TV." Wall Street Journal. Mar. 22, 1982. p. 1.

[82] "Why Satellite TV Worries European Socialists." Business Week. Sept. 20, 1982. p. 51.

[83] Newman, Barry. p. 1.

[84] "Why Satellite TV Worries European Socialists." Business Week. Sept. 20, 1982. p. 52.

[85] U.S. Congress. House. Committee on Science and Technology. Worldwide Space Activities, report for the Subcommittee on Space Science and Applications. (95th Congress, 1st session, H. Rept. 95-352). Washington, D.C., U.S. Government Printing Office, September 1977. p. 531.

[86] Dizard, Wilson P. "The U.S. Position: DBS and Free Flow." Journal of Communication. Spring 1980, p. 161.

[87] Ibid., p. 161.

The United States opposed adopting any binding principles governing DBS and proposed that although consultations should take place between nations transmitting and receiving DBS signals, states should not have the right to prohibit others from broadcasting. The Soviet Union draft principles emphasized the need for prior consent before broadcasting into any foreign countries. Argentina proposed principles similar to the Soviet Union, but added the need to insure validity of the information transmitted. Canada and Sweden proposed a compromise position in an attempt to satisfy concerns over prior consent and program control, while maintaining the principle of the free flow of information.[88]

After further negotiations, a new set of draft principles were offered by the Legal Subcommittee of COPUOS in 1978.[89] These served as the basis for additional discussions through 1981, but no consensus was reached. Unable to reach consensus, COPUOS referred to the matter to the General Assembly in 1981, but it asked the committee to make one more attempt to reach agreement during the 1982 session. No further progress was made in COPUOS during 1982, however, so once again the committee sent the issue to the General Assembly. On November 22, 1982, the U.N. Special Political Committee "approved a statement of principles under which satellite television could not be transmitted from one country to another direct to home receivers without advance formal agreement between the governments involved."[90] On December 10, 1982, the U.N. General Assembly passed a resolution containing these principles. Specifically provisions are included which state that:[91]

> An international direct television broadcasting satellite service shall only be established after the conditions set forth . . . above [notification and consultation with receiving nations] have been met and/or arrangements are made in comformity with the relevant instruments of the International Telecommunications Union and in accordance with these principles.

Although these "principles" have no binding authority, they may be expected to provide the basis for any future U.N. conventions governing DBS and a model for deliberations on direct broadcast satellite regulations in other international organizations.

3. *International Telecommunication Union [ITU] consideration of DBS*

The International Telecommunications Union [ITU], like the United Nations, first raised the issue of direct broadcasting from satellite two decades ago. In 1963, at the Extraordinary Administrative Radio Conference for Space Radio-communications, the broadcasting satellite service [BSS] was defined as:[92]

---

[88] World-Wide Space Activities. p. 533-535.

[89] Matte, Nicholas Mateesco. pp. 187-188.

[90] "Static Over the Skywaves." Chronicle of International Communication. November-December 1982. p. 2.

[91] Text of U.N. Document on Satellite Direct TV Broadcasting. New York Times, Dec. 11, 1982. p. 6.

[92] Dizard, Wilson P. op. cit. p. 158.

> A space service in which signals transmitted or restransmited by space stations, or retransmitted by reflection from objects in orbit around the earth, are intended for direct reception by the general public.

In addition, the International Radio Consultative Committee [CCIR] began to undertake technical studies on direct broadcast satellites which would serve as a basis for decisions on spectrum allocation. At the 1971 World Administrative Radio Conference [WARC] for Space Telecommunications, BSS received frequency allocations (including 500 MHz in the 11.7-12.2 GHz band) and procedures were adopted to create "international recognition and protection for BSS systems." [93]

The 1971 WARC also adopted a provision: [94]

> Which apparently makes prior consent (the right of a country to prohibit the reception of broadcasts from another country within its borders) a technical requirement by stating that "all technical means available shall be used to reduce, to the maximum extent practicable, the radiation over the territory of other countries unless an agreement has been previously reached with such countries"

Actual planning was conducted at the 1977 WARC for the broadcasting satellite service in the 12 GHz band. At this meeting, regions 1 and 3 of the ITU, which include Europe, Africa, Asia, and the South Pacific established a detailed, a priori plan for this service. A priori planning was supported in regions 1 and 3 because of the need to share the 12 GHz band with terrestrial services.

Region 2, in which the 12 GHz band is shared between fixed and broadcast satellite services, opposed detailed planning and instead "adopted in interim plan commonly referred to as arc segmentation." [95] Planning for BSS in region 2 was deferred until a later conference, now scheduled for June 1983.

At the 1979 World Administrative Radio Conference [WARC-79], the United States sought to clarify the allocations between fixed and broadcast satellite services in the 12 GHz band. The decision was made to allocate 11.7-12.1 GHz to fixed services and 12.3-12.7 GHz to broadcasting services, with the remaining 200 GHz to be divided at the 1983 Region 2 conference.[96]

As indicated earlier in this section, plans are already underway for U.S. preparations for the 1983 Regional Administrative Conference [RARC]. The 1983 RARC will be critical for determining the development of DBS services in the United States. The proposed delegation (to be led by former FCC Commissioner Abbott Washburn) currently is awaiting final White House approval and the Federal Communications Commission is expected to release its final Report and Order in March 1983 outlining the proposals for a U.S. position at the RARC.

Among the major issues to be resolved at the 1983 RARC are how to divide the 12.1 and 12.3 GHz band segment; what technical parameters should be established for BSS systems, and what type of planning approach should be adopted. It is expected that there will be a consensus on splitting the 12 GHz band evenly to allow for 500 GHz of bandwidth for DBS services, however, the United States may face difficulties both in receiving an adequate number of orbital slots to accommodate potential DBS demand in the United States and in establishing a flexible planning approach.[97] Although U.S. planners for the conference are hopeful that a satisfactory solution will be achieved, the major obstacle in this regard appears to be Canada which is expected to request six orbital slots based upon future rather than current needs.[98]

---

[93] Shrum, Richard E. "International Regulatory Aspects of Direct Broadcast Satellite in Direct Broadcast Satellite Communications: Proceedings of a Symposium." National Academy of Sciences, Apr. 8, 1980. p. 79.

[94] Smith, Marcia S. "The 1979 World Administrative Radio Conference: Implications for U.S. Preparations for Future ITU Conferences and Space Services." Congressional Research Service. Library of Congress. Washington, D.C., Sept. 3, 1981. p. 38.

[95] Smith, Marcia S. pp. 38-39.

[96] Ibid., p. 75.

D. Selected Issues

The introduction of direct broadcast satellites, like the introduction of any new technology, raises basic questions of public policy. Government policymakers have sought to promote opportunities for private enterprises to offer new communications services while at the same time protecting the public interest. The resulting issues range from questions of the role of the Government in regulating DBS systems, to the effects on existing communications providers, to the efficient use of the electromagnetic spectrum, to the impact on the viewing public. In addition, the debate on DBS policy encompasses international as well as domestic concerns revolving around the allocation of spectrum and the sovereign rights of nations.

1. 1983 Regional Administrative Radio Conference [RARC-83]

A number of issues surround the convening of RARC-83. The question of whether it is was in the best interest of the United States to authorize interim DBS prior to the 1983 meeting received attention in several FCC Notices of Inquiry during the last several years. Some respondents stated that approving interim DBS services would be detrimental to the negotiating position of the United States at RARC-83. The FCC concluded, however, that the existence of more concrete plans for DBS systems would strengthen the U.S. position at the Conference by providing valuable information useful in determining what international and domestic policies should be established. In addition, early approval of applications would have the advantage of enabling potential providers of these services to begin construction of DBS systems—a process which takes several years.[99]

Another concern regarding RARC-83 is whether the U.S. Government will be adequately prepared to represent the interests of both the Nation as a whole and the private sector which has invested in DBS systems. In the past, the executive branch was criticized for failing to assemble delegations and appoint chairmen in sufficient time for them to become fully versed on the issues and to solidify U.S. positions.[1] As indicated earlier in section C although a delegation chairman was selected some time ago, the actual delegation has not been approved by the White House. Committees in the

---

[97] "About the Canadian DBS Problem." Broadcasting. Jan. 17, 1983. p. 41.

[98] Ibid.

[99] Inquiry into the development of regulatory policy in regard to direct broadcast satellites for the period following the 1983 Regional Administrative Radio Conference, report and order, 47 Federal Register 31555 (July 21, 1982).

[1] Smith, Marcia S. op. cit.

House of Representatives have expressed concern over this lack of advanced planning and have sought through the oversight process to place pressure on the executive branch to improve in this area.[2]

The outcome of RARC-83 in terms of the technical parameters agreed to and the planning process developed raises additional substantive issues affecting the development of DBS in the United States. Of particular concern are such questions as the number of orbital slots the United States will receive, whether we will receive a block allocation, what technical standards will be determined, and the duration of the region 2 planning scheme. Although the U.S. position has not been formalized, it is expected that the United States will seek the most flexible approach possible to allow for technological developments and the addition of new systems.[3] While the United States favors this approach, other countries advocate a priori planning where allocations are made in advance so that each country is assured of space, whether or not they currently have a need to use it. In addition, the United States will be faced with accommodating the need for adequate orbital slots to satisfy domestic demand with the requests for orbital slots with neighboring countries, particulary Canada.[4] How successful the United States will be in accomplishing its goals at RARC-83 remains uncertain at this time.

2. Economic viability

There has been an ongoing debate concerning the size of the potential market for DBS services. Because direct broadcast satellite services are a new type of video delivery system and because they require a substantial capital investment, there is considerable risk associated with constructing a DBS system. A number of market surveys have been conducted with varying conclusions about the potential size of the DBS audience.

In 1982, an FCC advisory committee on DBS, established to assist in preparations for RARC-83, was unable to arrive at a concrete forecast for DBS demand. The committee estimated that by the year 2000 anywhere between 68 and 215 total channels would be required, including between 31 and 128 channels for standard television distribution.[5] The advisory committee stated that it was difficult to estimate demand because DBS systems could be used to distribute programing to a variety of community systems as well as to individual homes.[6]

Market surveys commissioned by several of the potential DBS providers provide optimistic figures concerning the public's willingness to pay for programing from direct satellite broadcasting. For example, Hubbard Broadcasting, owner of United States Satellite Broadcasting, released findings of a survey which showed that "more than half of cable subscribers and more than 60 percent of nonsubscribers will add direct satellite TV service when it becomes available * * * ."[7] Another study prepared for Comsat by Arthur D. Little, Inc., estimated that "at $24 per month, three-channel DBS is projected to obtain two to five million subscribers under the 'current' model and five to seven million subscribers under the 'adjusted' model."[8] These surveys reflect the belief that a substantial number of Americans who currently receive limited television channels and are unlikely to be served by cable will be willing to subscribe to a pay television service provided by direct broadcast satellites.

---

[2] U.S. Congress. House of Representatives. Committee on Government Operations. "Direct Broadcast Satellites: International Representation and Domestic Regulation." H. Rept. 97-730. Washington, D.C. U.S. Government Printing Office, Aug. 12, 1982.

[3] "RARC '83 Plans Progress; U.S. Policy Likely to Accent Flexibility." Satellite Week. v. 5, No. 7. Feb. 14, 1983 pp. 4-5.

[4] Ibid.

[5] "FCC's DBS Advisory Group Can't Agree On Demand." Communications Daily. June 7, 1982. pp. 2-3.

[6] Ibid.

Not all forecasts on DBS demand are so optimistic. One study done on the future of the cable industry found DBS systems highly risky and expensive with the potential for consumer demand unproven.[9]

Other analysts have pointed to the fact that: [10]

> By the time DBS gets started, the bulk of the nation's households will have access to cable television systems, which will provide more channels of service for the same or lower price. In addition to cable, many homes will be wired for pay-television systems, which may provide almost identical service to that proposed by many DBS applicants.

In addition to competing technologies, the cost of purchasing receiver equipment and the problem of providing unique programing make some analysts skeptical that the DBS market is as large as predicted by potential providers of direct satellite broadcasting services.

Whatever the ultimate outcome of this debate, there appears to be agreement that not all of the applicants will eventually succeed. Mr. Irving Goldstein of Comsat responded to skeptics by stating that only five million subscribers will be needed within 5 years of launching a DBS satellite to make a profit. However, he also acknowledged that the market could not support all the companies which intend to offer DBS services in the next several years.[11]

3. Displacement of current users of the 12 GHz band

One of the major controversies surrounding the approval of DBS services was the displacement of current users of the 12 GHz band. The 12.2-12.7 GHz band, which the FCC authorized for DBS downlinks, currently has a considerable number of fixed microwave users. Fixed services are used by: [12]

> Newspapers to transmit to remote printing plants, railroads to keep track of traffic, by manufacturers to relay data and videoconference among offices and plants, by utilities to video monitor remote facilities and to communicate with substations, by natural resource companies to facilitate exploration, refining and production activities and by local governments to enhance law enforcement and other public services.

---

[7] "Cable Homes Will Subscribe." Satellite Week. May 3, 1982. p. 3.

[8] Arthur D. Little, Inc. "Pay Television Services Via Direct Broadcast Satellite: Demand and Impact in the 1980s." May 1980. pp. 1-7.

[9] "Enormous Obstacles to DBS." Satellite Week. May 3, 1982. p. 3.

[10] Mayer, Caroline E. "7 Get Direct-Broadcast Rights." Washington Post, Nov. 5, 1982. p. C1.

[11] Landro, Laura. "Satellite TV May Not Live Up to Promise." Wall Street Journal. June 28, 1982. p. 17.

[12] U.S. Congress. House. Committee on Energy and Commerce. Subcommittee on Telecommunications, Consumer Pretection, and Finance. "Satelllite Communications/Direct Broadcast Satellites." Dec. 15, 1981. 97th Congress, 1st Session U.S. Government Printing Office, serial No. 97-81.

The FCC determined that the benefits to be achieved by initiating DBS service outweighed the costs associated with moving existing terrestrial users to another frequency band. The users did not agree with that conclusion and fought against it, citing the fact that the cost of moving to another frequency would be substantial and that services would be degraded. According to the director of communications for the county of Los Angeles, "loss of the 12.2-12.7 GHz frequencies will have a devastating effect on the reliability of Los Angeles County's safety-of-life and property services as well as place an economic burden on the county's citizens that is totally unwarranted * * *."[13]

In an effort to ease the burden on the current terrestrial users of the band, the FCC proposed in its report and order in docket 80-603 to provide for a 5-year transition period in which users could move to a new location. Comsat also suggested that DBS operators reimburse existing nonprofit, public service microwave users to cover the costs associated with moving to another frequency.[14] In addition, recently, the FCC proposed to allow fixed microwave users in the 12 GHz band to share certain frequencies in the 2, 6, 13, and 18 GHz band currently in use by common carrier, microwave, private operational fixed, broadcast auxiliary, and cable TV relay services.[15] This would provide less expensive alternatives to the current users than moving to bands at 18 GHz.

In addition, on December 21, 1982, the Senate approved Executive Treaty Document No. 97-21, the Treaty on International Radio Frequencies [WARC-79]. The document contains a proviso directing that DBS service should be implemented in the 12.2-12.7 GHz band with minimal disruption to existing users.[16]

4. Effect on existing broadcasting services

The impact of DBS on local broadcasting is another area of considerable debate. Since DBS systems can provide video services directly to the home, they can bypass local network affiliates and independent stations. This has raised concern both because of the economic harm which may result to local broadcasting and because local input and control of programing will be diminished. Questions have been raised concerning how DBS might fragment local audiences and split advertising revenues to the point where it causes local stations to fail; how DBS might siphon off the best programing so that "free" television could not compete; and how DBS might not satisfy public service needs.[17] This controversy recently was highlighted when FCC Commissioner Stephen Sharp gave a speech suggesting that it would be economically more attractive for television networks to use DBS as a delivery mechanism than to rely on distribution through local affiliates.[18]

---

[13] Ibid., p. 144.

[14] Ibid., p. 44.

[15] "Sharing to Be the Answer for 12 GHz Microwave Users." Broadcasting magazine. Jan. 17, 1982. p. 42.

[16] Congressional Record. Dec. 21, 1982. S. 15918.

[17] Sardella, Vincent and Kim Degnan. "Satellite Broadcasting to Homes." Telecommunications Policy. June 1981.

[18] "FCC Commission Sharp Says DBS May Doom Network Affiliations." Communications Daily. Jan. 19, 1983. v. 3, No. 13. p. 1.

Another element of this question was raised at hearings of the House Subcommittee on Government Information and Individual Rights, Committee on Government Operations. Committee members expressed concern that local communities would not be able to provide input to the content of DBS programing since it would be a national or regional broadcasting service.[19]

What impact DBS might have on the cable industry and other types of video delivery systems, such as subscription television [STV], multipoint distribution system [MDS], and satellite master antenna television [SMATV] remains unclear. While some analysts contend that DBS audiences will be concentrated in areas where systems such as cable or MDS are not economical, others suggest that DBS and cable may become direct competitors. Ultimately, the quality of programing and the cost to individual consumers will be key determinants in the success of these various systems.

5. Government regulation

As a new technology, direct broadcast satellites raise the question of what type of regulatory scheme is most appropriate. A substantial amount of debate occurred on this question during the FCC's consideration of Docket 80-603 for establishing interim DBS service. Legal authorities analyzed the options available to the FCC based upon existing broadcasting and common carrier models and upon the authority of the FCC to classify DBS as a hybrid service.[20]

As outlined in section B., the report and order in Docket 80-603 opted for a flexible regulatory approach to DBS. Reflecting the recent trend of the Commission toward deregulation and promotion of competition, the report concluded that the marketplace would be the most effective mechanism for regulating DBS. As a result, applicants were permitted to select their desired regulatory classification as a common carrier, broadcaster, or hybrid service provider. Each licensee will be regulated upon the basis of the chosen classification, that is, broadcasters would be subject to existing broadcasting regulations, while common carriers would be regulated as such.

The FCC further stated that for interim DBS service no technical requirements beyond those imposed by international agreement would be established, no ownership limitations would be instituted, and no access requirements would be imposed.[21]

6. High definition television [HDTV]

Another issue which arose during discussions on direct broadcast satellites was the use of the 12 GHz band for transmitting high definition television. The major proponent of HDTV in the United States is CBS, Inc. which maintains that it is a significant advance in television technology and that the 12 GHz band should be reserved for its use. The technology which CBS is developing in conjunction with Nippon Hoso Lyokai [NHK] of Japan would replace the current 525-line television system with an 1,125-line system having, "increased sharpness or resolution, sharply improved color quality, a wide screen aspect ratio, and stereophonic sound." [22]

---

[19] "Direct Broadcast Satellites; International Representation and Domestic Regulation." Ibid., p. 18.

[20] See: Federal Communications Law Journal. v. 33, spring 1981; and Federal Communications Commission. Office of Plans and Policies. Policies for Regulation of Direct Broadcast Satellites. Washington, D.C. September 1980.

[21] Inquiry into the development of regulatory policy in regard to direct broadcast satellites for the period following the 1983 Regional Administrative Radio Conference, report and order, 47 Federal Register 31555 (July 21, 1982).

CBS argued that: [23]

> The allocation of the 12 GHz spectrum represents a brief, extraordinarily important 'window' for the development of an HDTV broadcast television service. Application of this valuable spectrum to conventional television technology would be an enormous waste of national resources and a loss of a unique national opportunity.

While other potential providers of DBS services admit that HDTV is an interesting technological development and would consider offering it at some future point, they contend that it should not delay initiation of interim DBS systems transmitting conventional television signals. Specifically, they cite the fact that HDTV—although tested successfully—is still under development, that it uses considerably more spectrum space than existing television transmissions reducing the number of channels available, and that both producers of programing and consumers would need to purchase expensive new equipment. [24]

The FCC concluded in its Report in Docket 80-603 that the 12.2-12.7 GHz may "be used either for HDTV or for conventional television signals, as spectrum allocation permits and the market dictates." [25]

E. CONGRESSIONAL INTEREST

1. Congressional hearings and reports

A number of congressional hearings during the 97th Congress have focused on the question of direct broadcast satellites. For example, as part of oversight hearings on rural telecommunications, the Senate Committee on Commerce, Science, and Transportation received testimony on the potential that direct broadcast satellites might offer for increasing low cost television services to rural areas. [26]

Two committees in the House of Representatives expressed interest in the DBS issue as well. The House Committee on Energy and Commerce, Subcommittee on Telecommunications, Consumer Protection, and Finance, held hearings on December 15, 1981, on this topic. Representatives of several applicants for DBS systems, broadcasting groups, and other communications experts testified on the potential of and problems associated with this new technology. [27] While no consensus was achieved among the witnesses, the hearings offered an opportunity for both proponents and opponents of DBS to express their views.

---

[22] Satellite Communications/Direct Broadcast Satellites. p. 111.

[23] Satellite Communications/Direct Broadcast Satellites. p. 110.

[24] Ibid., p. 62.

[25] Inquiry into the development of regulating policy in regard to direct broadcast satellites for the period following the 1983 Regional Administrative Radio Conference, report and order, 47 Federal Register 31555 (July 21, 1982).

[26] U.S. Congress. Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Communications. Rural Telecommunications. Hearings, 97th Congress, 1st session, June 22, 1981. Washington, D.C., U.S. Government Printing Office, 1981.

[27] U.S. Congress. House of Representatives. Committee on Energy and Commerce. Subcommittee on Telecommunications, Consumer Protection, and Finance. Satellite Communications/Direct Broadcast Satellites. Dec. 15, 1981. 97th Congress, 1st session, Washington, D.C., U.S. Government Printing Office, serial No. 97-81.

The House Committee on Government Operations, Subcommittee on Government Information and Individual Rights held several days of hearings which addressed aspects of direct broadcasting satellites. On October 23, 1981, the subcommittee held a hearing on international broadcasting and direct broadcast satellites. Subsequently, the committee issued a report entitled, "International Shortwave Broadcasting and Direct Broadcast Satellites: Voice of America, Radio Free Europe/Radio Liberty, Radio Marti." [28]

The report recommended that: [29]

> An Executive Branch task force * * * conduct a study of the potential of direct broadcast satellites for shortwave radio transmissions by United States international broadcasters.

Senator Larry Pressler introduced Senate Resolution 243 on November 12, 1981, expressing the sense of the Senate that the Government should undertake such a study. Although the resolution never passed, such a study is currently underway by the executive branch.

During Federal Communications Commission Oversight hearings by the House Committee on Government Operations Subcommittee on Government Information and Individual Rights on September 22, 1981, a number of questions were raised concerning direct broadcast satellites. As a result of these hearings, the committee issued the report, "Direct Broadcast Satellites: International Representation and Domestic Regulation" on August 12, 1982.[30] Among the recommendations of the report were several supporting the improvement of U.S. preparations for international conferences, such as the 1983 RARC on broadcasting satellites, and one suggesting that the Federal Communications Commission "assess the impact of dislocation of those new services now operating in the 12 GHz band." [31]

2. WARC-79 treaty ratification

On December 21, 1982, the Senate passed Senate Executive Treaty Document No. 97-21, the Treaty on International Radio Frequencies [WARC-79]. The Senate added two provisos to the Treaty Document which, while not affecting the international obligations of the United States, are binding on the President. One of these states: [32]

> That in the implementation of the treaty for the United States, the introduction of the Direct Broadcasting Satellite Service into the 12.2-12.7 GHz band shall be carried out in a manner which minimizes unreasonable disruptions to existing uses in that band.

Upon proposing this provisio, Senator Percy commented that: [33]

---

[28] U.S. Congress. House. Committee on Government Operations. "International Shortwave Broadcasting and Direct Broadcast Satellites: Voice of America, Radio Free Europe/Radio Liberty, Radio Marti." 97th Congress, 1st Session, H. Rep. 97-398. Washington, D.C. U.S. Government Printing Office, 1981.

[29] Ibid., pp. 3-4.

[30] U.S. Congress. House. Committee on Government Operations. "Direct Broadcast Satellites: International Representation and Domestic Regulation." 97th Congress, 2d Session, H. Rept. 97-730. Washington, D.C., U.S. Government Printing Office, 1982.

[31] Ibid., p. 3.

[32] Congressional Record. Dec. 21, 1982. p. S15918.

[33] Ibid. p. S15920.

It is my understanding that the Federal Communications Commission has already taken initial steps to alleviate the concerns which prompted this proviso, so it is not expected to create any difficulties.

3. Congressional role

Congress has refrained from taking a direct role in determining how DBS services should be implemented in the United States, preferring to leave that to the Federal Communications Commission. At the same time, it has not ignored the issue. The various hearings, reports, and the WARC-79 Treaty proviso instead reflect a desire on the part of Congress to provide a forum for the expression of differing perspectives on direct broadcasting satellites. In addition, it may be expected that Congress will continue to oversee the activities of the Federal Communications Commission in initiating this new service so that all parties are treated fairly and to insure that the executive branch adequately represents the United States at international meetings on direct broadcast satellites.

Appendix A Memorandum on Legal Issues

22 F.C.C.2d 86, 128 (1970)

1. With respect to the question of whether the Commission has legal power to authorize any nongovernmental entity (common carrier or noncarrier) to establish and operate domestic communication satellite facilities, the parties commenting in this proceeding have taken several positions. Some, like ABC and the Ford Foundation, urge that the Commission has broad authority under the Communications Act of 1934 and the Communications Satellite Act of 1962 to authorize either type of entity to establish such facilities. A.T. & T. and ITT assert that the Commission has such broad power as a matter of law but urge that a noncarrier system should not be authorized, at least at this juncture, as a matter of policy. Other common carriers allege that legal capacity to authorize a noncommon carrier domestic system is lacking and that such a system should not, in any event, be authorized as a matter of policy. Comsat, in particular, argues that under the 1962 act it alone may be authorized to own domestic satellites

BEST COPY AVAILABLE

A2

and to utilize earth stations which may be owned by it and other carriers. On the other hand, ARINC and ATA question whether Comsat is legally qualified to provide domestic service in view of its involvement in Intelsat.

2. After full consideration of the various briefs submitted in support of these positions, the Commission is of the view that the Communications Act of 1934 and the 1962 act clearly empower the Commission to authorize domestic communications satellite facilities to be owned by any entity, either common carrier—including Comsat—or noncarrier, as the national public interest requires.

3. The 1934 act, which directs the Commission to provide a rapid, efficient, Nation-wide and worldwide wire and radio communication service (47 U.S.C. 151), applies to all interstate and foreign communciation by wire or radio and all interstate and foreign transmission of energy by radio, which originates and/or is received within the United States and to the licensing and regulating of all radio stations (47 U.S.C. 152(a)). A license from the Commission is required for all radio stations except Government-owned stations (47 U.S.C. 301, 303, 305, 307, 308, and 309). By definition, radio station is a station equipped to engage in radio communication or radio transmission of energy (47 U.S.C. 153(k)). Communication by radio is defined to include all instrumentalities, facilities, apparatus, and services incidental to the transmission by radio of writing, signs, signals, pictures, and sounds of all kinds (47 U.S.C. 153(b)), and transmission of energy by radio similarly includes both such transmission and all instrumentalities, facilities, and services incidental to such transmission (47 U.S.C. 153(d)). These all-inclusive definitions clearly include non-Government satellite and earth station facilities used for interstate communication or transmission of energy by radio, which originates and is received within the United States.

4. The Commission's jurisdiction under the plain language of the 1934 statute to license and regulate domestic satellite facilities is not affected by the circumstance that the radio transmission involves stations located in space and a new technology not explicitly mentioned in that act. *California Interstate Telephone Co.* v. *Federal Communications Commission*, 328 F. 2d 556 (C.A.D.C.). Section 303(g) directs the Commission to study new uses for radio, provide for experimental uses of frequencies, and generally encourage the larger and more effective use of radio in the public interest (47 U.S.C. 303(g)). The policy underlying this section was stated during the Congressional hearings on the 1934 act. "Our supremacy in radio cannot be maintained except by active encouragement and development of its use. Its possibilities are almost untouched today * * *. Who knows what future developments may bring?" Hearings on H.R. 8310 before the House Committee on Interstate and Foreign Commerce, 73d Cong., Second sess., p. 21. Section 303(g) makes clear that Congress placed an affirmative duty on the Commission to experiment with and develop the most desirable deployment and utilization of the Nation's communications facilities (*Connecticut Committee Against Pay-TV* v. *Federal Communications Commission*, 301 F. 2d 835, 837 (C.A.D.C.), *cert. den.* 371 U.S. 816.

5. The 1934 act has been uniformly construed as granting broad powers to the Commission which do not depend on a specific reference to the particular service, technology or practice in the statute. In *National Broadcasting Company* v. *United States*, 319 U.S. 190, 217, 219, the Supreme Court stated with respect to the Commission's comprehensive power over newly developing instrumentalities of radio communication:

> "The avowed aim of the Communications Act of 1934 was to secure the maximum benefits of radio to all the people of the United States. To that end Congress endowed the Communications Commission with comprehensive powers to promote and realize the vast potentialities of radio.
>
> "* * * True enough, the act does not explicitly say that the Commission shall have power to deal with network practices found inimical to the public interest. But Congress was acting in a field of regulation which was both new and dynamic. * * * In the context of the developing problems to which it was directed, the act gave the Commission not niggardly but expansive powers."

The statutory public interest standard leaves wide discretion and calls for imaginative interpretation. *Federal Communications Commission* v. *RCA Communications, Inc.*, 346 U.S. 86, 90. See also *United States* v. *Storer Broadcasting Co.*, 351 U.S. 192, 203 (the Commission's authority covers new and rapidly

BEST COPY AVAILABLE

developing fields); *Federal Communications Commission v. Pottsville Broadcasting Co.*, 309 U.S. 134, 138 (underlying the 1934 act is recognition of the rapidly fluctuating factors characteristic of the evolution of broadcasting and of the corresponding requirement that the administrative process possess sufficient flexibility to adjust itself to these factors). See also, *United States v. Southwestern Cable Company*, 392 U.S. 157.

6. In administering the 1934 act the Commission has exercised this wide discretion and comprehensive power to authorize both common carrier and private communications systems according to its judgment as to the requirements of the public interest. See, e.g., *Allocation of Frequencies in the Bands above 890 Mc./s.*, 27 F.C.C. 359, 29 F.C.C. 825.[1] The Commission has also found that the public interest may be served by the joint common carrier ownership of cable facilities (*American Telephone and Telegraph Co. et. al.*, 37 F.C.C. 1151, 1157) and by shared use of private systems on a nonprofit, cooperative basis (*Amendment of the Commission's Rules to Permit Expanded Cooperative Sharing of Operational Fixed Stations*, 4 F.C.C. 2d 404). In the latter connection the Commission said (4 F.C.C. 2d at 417):

> "The touchstone for the regulation of the use of radio is the public interest and we think that, under that standard, we have ample authority to permit cooperative use of radio stations if we find, as we have, that the public interest would be served and the larger and more effective use of radio would be encouraged."

The Commission also claimed (ibid.) ample authority to prescribe any special method of regulating the cooperative use of private systems that would best serve the public interest. See *Philadelphia Television Broadcasting Co. v. F.C.C.*, 123 U.S. App. D.C. 298, 359 F. 2d 282.

7. The same licensing flexibility applies to the authorization of non-Government domestic communications satellite facilities by the Commission. We are not persuaded by Comsat's argument that the 1962 act superseded or restricted the Commission's powers under the 1934 act in the domestic field by requiring that any domestic system be authorized to Comsat alone (and/or other carriers in the case of earth stations). The Commission's clear jurisdiction over commercial domestic satellite facilities under the 1934 act was not withdrawn by the 1962 act, which legislated in the field of international satellite communications. The declared purpose of the 1962 act was to establish a global satellite communications system in conjunction and in cooperation with other countries (sec. 102(a)) and to provide for United States participation in the global system * * * in the form of a private corporation, subject to appropriate regulations (sec. 102(c)). H.R. Rept. No. 1636, 87th Cong., second sess., p. 7. The attention of Congress centered on the early establishment of an international system to enable the United States to move ahead and assert a position of leadership at the Extraordinary Administrative Radio Conference of the International Telecommunications Union called in 1963 to allocate frequencies for communications satellite systems. See, e.g., H.R. Rept. 178, 89th Cong., first sess., p. 22; H.R. Rept. No. 1636, 87th Cong., second sess., p. 8; 108 Cong. Rec. 11825, 15026, 15124, 16416, 16569, 16574 (1962). Moreover, in 1962 the technology consisted of random orbit satellites (like Telstar), orbiting the globe and better suited to international than to domestic use. Synchronous satellites, which make domestic service more economically attractive, were not contemplated in the immediate future. The international thrust of the 1962 act is also reflected in the bill's referral to the foreign policy committees, in the functions accorded to the President (to be executed by the State Department) in section 201(a), and in the concern with world peace and understanding (sec. 102(a)), services to economically less developed countries and areas (sec. 102(b)), foreign participation (sec. 201(a)(5),

---

[1] Since the "Communications Act must be read as a whole" (*United States v. Storer Broadcasting Co.*, 351 U.S. 192, 203), the Commission has, of course, been mindful that the authorization of private systems not result in such substantially adverse economic effects upon common carriers as to impair their ability to provide adequate service to the general public. By the same token, the Commission "cannot let its decisions in the radio carrier field interfere with its responsibilities in the television broadcasting field. In both fields, it must make available, so far as possible, to all people of the United States, adequate and efficient service." *Carter Mountain Transmission Corp. v. Federal Communications Commission*, 321 F. 2d 359 (C.A.D.C.), *cert den.* 375 U.S. 951.

BEST COPY AVAILABLE

102(a), 305(a)(1)), communication to a particular foreign point (sec. 201 (c)(3)), and business negotiations * * * with any international or foreign entity (sec. 402).

8. In asserting that the 1962 act also superseded the Commission's powers under the 1934 act in the domestic field, Comsat relies on the last sentence in section 401 which states: "Whenever the application of the provisions of this act shall be inconsistent with the application of the provisions of the Communications Act, the provisions of this act shall govern." But this statement was made in the context of making Comsat a common carrier fully subject to the provisions of title II and title III of the 1934 act. It is more reasonably construed as applying to conflicts between the two acts insofar as the global international system is concerned, than as effecting a substantive extension of the provisions of the 1962 act to the domestic field. Indeed, many of the provisions of the 1962 act make sense only in the international field and are anomalous in a domestic context. See, e.g., sections 201(a) (4) and (5), section 201(c)(3), section 305(a)(1), and section 402.

9. "Repeals by implication are not favored" (*Federal Trade Commission* v. *A.P.W. Paper Co.*, 328 U.S. 193, 202), and it would be unreasonable to assume that Congress, in enacting provisions tailored to an international system established in conjunction and in cooperation with other countries, would have supplanted the 1934 act in the domestic field—traditionally only of sovereign concern—without mentioning that it was doing so. The 1962 act does not contain any express requirement that domestic satellite service shall be provided in accordance with the provisions governing the global system or any statement withdrawing the Commission's powers under the 1934 act to authorize an additional non-Government domestic system. On the contrary section 102(d) states:

> "It is not the intent of Congress by this Act to preclude the use of the communications satellite system for domestic communication services where consistent with the provisions of this Act nor to preclude the creation of additional communications satellite systems, if required to meet unique governmental needs or if otherwise required in the national interest."

The denial of intent to preclude domestic use of the global system clearly implies that the 1962 act might otherwise be construed as prohibiting such use. It makes little sense to argue, as Comsat does based on the use of the phrase "national interest" rather than "public interest," that Congress adopted a scheme whereby the Comsat system was generally given a monopoly both internationally and domestically in the face of the fact that Congress found it necessary to provide explicitly against the possibility that the Comsat system might not be regarded as available for domestic use. Nor is it reasonable to assume that Congress thereby intended to foreclose competition within the domestic field. In short, this permissive language cannot be equated with a mandatory requirement for use of the global system, and militates strongly against such a requirement.

10. The legislative history of the 1962 act shows that Congress contemplated that an additional system might be authorized to an entity other than Comsat. Language almost identical to section 102(d) appears in the implementation of policy provisions (sec. 201), where Congress provided that the President shall:

> "(a)(6) take all necessary steps to insure the availability and appropriate utilization of the communications satellite system for general governmental purposes except where a separate communications satellite system is required to meet unique governmental needs, *or is otherwise required in the national interest.* * * *"

When the bill which became the 1962 act was reported to the Senate, section 201(a)(6) did not contain the italicized words. Senator Church, a member of the Foreign Relations Committee considering the bill, was concerned with this omission and the fact that the operative language of the bill did not conform with the declaration of policy. To the committee report on the bill he appended his separate views on this point, stating (S. Rept. No. 1873, 87th Cong., Second sess., pp. 14–15):

> "The wisdom of this last clause 'or if otherwise required in the national interest' is perfectly apparent. We cannot now foretell how well the corporate instrumentality established by this act will serve the needs of our people. If

BEST COPY AVAILABLE

it should develop that the rates charged are too high, or the service is too limited, so that the system is failing to extend to the American people the maximum benefits of the new technology, or if the Government's use of the system for, Voice of America broadcasts to certain other parts of the world proves excessively expensive for our taxpayers, then certainly this enabling legislation should not preclude the establishment of alternative systems, whether under private or public management. And just as certainly is that gateway meant to be kept open, in case we should ever need to use it, by the language to be found in the bill's 'declaration of policy purposes' and to which I have referred."

On the floor, in speaking in support of his amendment to conform these two provisions of the act, Senator Church repeated these same views verbatim and his amendment was agreed to.

11. The legislative history also refutes Comsat's contention that new legislation would be required for Commission authorization of any additional system different from that prescribed in the 1962 act. The Senate rejected an attempt by the House to reserve to Congress the right to provide for additional satellite systems. When the legislation was first passed by the House (H.R. 11040, as passed by the House on May 3, 1962), section 102(d) provided:

> "The Congress reserves to itself the right to provide for additional communications satellite systems if required to meet unique governmental needs or if otherwise required in the national interest."

However, the Senate refused to accept the House language and substituted the current version of section 102(d), to which the House acceded. Since Congress was repeatedly told throughout the 1962 hearings that the Commission had jurisdiction to authorize non-Government communication satellite facilities by virtue of the 1934 act,[2] the defeat of the House language shows that Congress considered and rejected the position that further legislation is a prerequisite to Commission authorization of different domestic facilities.

12. That the 1962 act was not intended to withdraw the Commission's licensing flexibility as to domestic systems under the 1934 act is further indicated by the postlegislative comments of Senator Pastore, floor manager of the 1962 bill, in hearings before the Senate Commerce Committee on August 17, 1966. In questioning representatives of the Ford Foundation and Comsat on the meaning of section 102(d), Senator Pastore stated that it was his understanding then and at the time of the drafting and enactment of the 1962 act that Comsat was established for the purpose of taking and holding a position of leadership for the United States in the international communications satellite field, but that the law and

---

[2] The Commission's chairman and other commissioners repeatedly told House and Senate Committees that the Commission had power under the 1934 act to authorize non-Government communications satellite facilities for commercial use. See, e.g., hearings on communications satellites before the House Committee on Interstate and Foreign Commerce, 87th Cong., first sess., pt. 1, pp. 6, 86; hearings on communications satellites before the House Committee on Science and Astronautics, 87th Cong., first sess., pt. 1, pp. 498–499; hearings on space satellite communications before the Subcommittee on Monopoly of the Senate Select Committee on Small Business, 87th Cong., first sess., pp. 652, 662, (672), 471. Representatives of the Justice Department took the same view as to the Commission's jurisdiction under the 1934 act. See, e.g., hearings on communications satellites before the House Committee on Interstate and Foreign Commerce, 87th Cong., first sess., pt. 1, p. 153; hearings on S. 2650 and S. 2814 before the Senate Committee on Aeronautical and Space Sciences, 87th Cong., second sess., pp. 405, 407, 408. The following exchange took place between Senator Kefauver and then Assistant Attorney General Katzenbach (hearings on antitrust problems of the space communications system before the Subcommittee on Antitrust and Monopoly of the Senate Committee on the Judiciary, 87th Cong., second sess., pt. 1, pp. 55–56):

"Senator KEFAUVER [speaking of Comsat]. Why couldn't some of these channels be held open for the television companies * * * for all of these other hundreds of users that would not come under FCC jurisdiction?

"Mr. KATZENBACH. They would all come under FCC jurisdiction, sir, because as soon as you are using these facilities, as soon as you are using the radio spectrum, you are under FCC jurisdiction.

"Senator KEFAUVER. But you are forcing them to make a deal with one of the communications carriers, and what if they don't want to make a deal with a communications carrier?

"Mr. KATZENBACH. Then they have to get into the business themselves, sir. And I suppose that if that is a practical way of doing it, then that is what should be done. But these are responsibilities, as to who is to be licensed for what purposes, which are given to the Federal Communications Commission."

BEST COPY AVAILABLE

policy as to domestic systems were left wide open. Senator Pastore stated, inter alia, that it was his understanding now, as it was then, that this is not a field that belongs exclusively under the act to Comsat or to anyone else, and that:

> "I think we all agree that Comsat could do it. It is a decision of the FCC, which way they want to go. They have a perfect right to apply for this under the law. It doesn't preclude anybody—Ford, ITT, anybody else. I think it is an open field."

See hearings before the Subcommittee on Communications of the Senate, Committee on Commerce, 89th Cong., second sess. (Serial 89–78), pp. 103–4, 116, 128–130.

13. And, finally, in light of section 102(d) and Senator Pastore's comments (par. 12 above), we see no merit to the contention that Comsat may be legally disqualified from entering the domestic field because of its involvement in Intelsat. Since Congress did not intend to preclude use of the global system for domestic communication services, it follows a fortiori that such services may be provided by the United States participant in the global system. The possible advantages or disadvantages accruing from Comsat's relationship with Intelsat are considerations to be weighed as a matter of policy, but we find no legal bar.

14. Accordingly, we conclude that the Commission possesses the requisite legal power under the Communications Act of 1934 and the 1962 act to authorize any entity, either common carrier or noncommon carrier or some combination of both, to own and operate satellite facilities and earth stations to provide domestic satellite communications services, or to determine that such services should be provided in whole or in part, through the facilities of Intelsat. The Commission may authorize domestic communications satellite facilities upon finding that such facilities would serve the public convenience, interest, or necessity under the 1934 act and are required in the national interest under the 1962 act.

BEST COPY AVAILABLE

Appendix B History of F.C.C. Docket 16495
22 F.C.C.2d 86, 108 (1970)

A. HISTORY OF THE PROCEEDING

1. The history of this proceeding dates from an application filed with this Commission on September 21, 1965, in which the American Broadcasting Cos., Inc. (ABC), requested "* * * a satellite authorization in the Auxiliary Radio Broadcast Service for television broadcast distribution purposes." An opposition to the application was filed by the Communications Satellite Corp. (Comsat), to which ABC replied. The application was tendered under part 74 of the Commission's rules and regulations and requested waiver of parts 2, 21 and 74, as might be necessary. ABC proposed use of the frequency bands 3700–4200 and 5925–6425 MHz, for transmitting network programs from earth stations in New York and California, via satellite, to ABC-owned and affiliated stations throughout the United States, including Alaska, Hawaii, Puerto Rico, and the Virgin Islands. ABC also proposed to provide facilities for the interconnecting of noncommercial educational television stations in those areas.

2. The application proposed new use of space communication techniques and presented novel questions of law and policy which would have to be resolved before any Commission action on the application could be taken. Accordingly, on March 2, 1966, the Commission returned the ABC application, without prejudice to appropriate refiling in light of the outcome of a public inquiry which was simultaneously instituted.

3. Because the application by ABC raised novel problems, the Commission believed that the public interest would be served by obtaining the views and comments of interested parties on a series of questions as a means of determining what further actions were warranted by the Commission. Therefore, the Commission adopted a notice of inquiry on March 2, 1966, in which it cited its statutory responsibility to study new uses for radio and generally encourage the larger and more effective use of radio in the public interest (sec. 303(g) of the Communications Act of 1934, as amended).

4. The March 2, 1966, Notice of Inquiry (31 F.R. 3507) invited comments on the following specific questions:

(*a*) Whether, as a matter of law, the Commission may promulgate policies and regulations, looking toward the authorization of nongovernmental entities to construct and operate communications satellite facilities for the purpose of meeting their private or specialized domestic communications requirements. This proceeding is not concerned with the question of whether communications common carriers may be authorized to construct and operate communication-satellite facilities for domestic purposes. (Parties submitting comments in this matter should do so in separate legal briefs);

(*b*) The effect or impact of any such authorization upon the policies and goals set forth by the Communications Satellite Act and upon the obligations of the U.S. Government as a signatory to the executive agreement establishing interim arrangements for a global commercial communications satellite system;

(*c*) Whether, as a matter of policy, it would be in the public interest to grant such authorization considering:

(1) The amount of frequency spectrum now available for the communication satellite service under the Commission's rules;

(2) The extent to which terrestrial facilities are or may be available to provide the services contemplated;

(3) The potential economic effects on common carriers: and

(4) The potential benefits (e.g., improved quality and reduced cost of service) which might result from the grant of such authorizations.

(*d*) Is it technically feasible to accommodate the space service contemplated in light of the requirement:

(1) That the power-flux density produced at the earth's surface in the band 3700–4200 Mc./s. by emissions from a space station employing wide-deviation frequency (or phase) modulation not exceed −149 dbW/m.^{2} in any 4 kc./s. band for all angles of arrival nor a total of −130 dbW/m.^{2} for all angles of arrival;

(2) That the power-flux density produced at the earth's surface in the band 3700–4200 Mc./s. by emissions from a space station employing other

BEST COPY AVAILABLE

B2

than wide-deviation frequency (or phase) modulation not exceed −152 dbW/m.^{2} in any 4 kc./s. band for all angles of arrival;

(3) That earth stations receiving signals from space stations in the band 3700–4200 Mc./s. be so located with respect to the existing common carrier microwave complex in that band that they are not subjected to harmful intereference from such terrestrial microwave systems;

(4) That transmitting earth stations in the band 5925–6425 Mc./s.:

(a) Not exceed a mean effective radiated power of 45 dbW in any 4 kc./s. band in the horizontal plane; and

(b) Not cause harmful interference to the existing common carrier microwave complex in the same band.

(e) Other relevant matters to which the respondents wish to address themselves.

B. FILING OF INITIAL COMMENTS (AUGUST 1966)

5. On or before August 1, 1966, comments were filed by 19 parties. (See list of all parties filing in this proceeding in app. A.) Several parties argued that this Commission has authority under existing legislation including the Communications Act of 1934, as amended, and the Communications Satellite Act of 1962, to authorize entities other than communications common carriers to establish and operate communication satellite services to meet their private or specialized needs. This position was supported by ABC; the American Telephone & Telegraph Co. (A.T. & T.); the Columbia Broadcasting System (CBS); Dow Jones & Co., Inc.; the Ford Foundation; ITT World Communications, Inc. (ITT Worldcom); the National Association of Educational Broadcasters (NAEB); the National Association of Manufacturers (NAM); and the National Broadcasting Co. (NBC). Opposition to this view, based upon an interpretation of the two named acts, was contained in comments of Comsat; G.T. & E.; the Hawaiian Telephone Co.; and Western Union Telegraph Co.

6. ABC and NBC challenged the adequacy of the facilities of existing carriers to meet present and foreseeable television network program distribution requirements—a challenge disputed by A.T. & T. ABC proposed that it be authorized, individually or in conjunction with other commercial or noncommercial educational network organizations, to construct and operate (by joint venture or otherwise) communications satellite facilities for the purpose of transmitting network programs (commercial and educational) to affiliated and associated stations within the United States and its insular possessions. ABC is prepared to join with other entities to create a nonprofit organization to construct and operate such facilities.

7. Several communications common carriers challenged the economic and technical viability and feasibility of privately owned systems, and presented a variety of policy considerations in support of their conclusion that private ownership and operation of domestic communication satellite facilities are not technically or economically feasible. On the basis of historical, economic, technical, and policy considerations, A.T. & T., Comsat, Hawaiian, ITT Worldcom, and Western Union Telegraph urged the Commission to find it in the public interest that domestic communication satellite service should be provided by a multipurpose, common carrier owned satellite system. Comsat, urging that the Commission was limited by the 1962 act to authorizing the space segment of a domestic system to Comsat alone and the earth stations to Comsat and qualified carriers, attached its technical plan for meeting various domestic requirements. A.T. & T. stated that it was engaged in studying possible domestic uses of satellites and in formulating plans where their use appeared to be advantageous. Western Union took the position that joint undertakings by the carriers are possible and perhaps desirable, but urged that present authorizations should run to a particular carrier in those instances where that carrier is seeking to establish a system to meet its own needs.

8. A number of parties urged the Commission not to reach any decision at this time which would preclude consideration in the near future or eventual establishment of privately owned or specialized domestic communication satellite facilities. Several of the parties stressed the necessity of leaving a choice available to potential users as to how they may arrange to meet their domestic telecommunication needs. JFD Electronics Corp. (JFD) in its comments asked the Com-

BEST COPY AVAILABLE

mission to expand the proceeding to investigate and provide for the possibility of a satellite-originated television broadcasting service in the upper part of the UHF band (channels 70 to 83). JFD contended that there is no congressional intent in the Communications Satellite Act of 1962 to grant Comsat a monopoly over domestic satellite systems.

9. The Carnegie Commission on Educational Television (Carnegie) advised the Commission that it was studying educational television in every aspect and that it presently was studying alternative methods of program distribution, including possible use of satellites, and that discussions were in progress with the National Aeronautics and Space Administration concerning a communications satellite system designed for noncommercial television. The statement was filed to call this Commission's attention to the studies in progress, and to encourage this Commission to retain flexibility on the issues relating to educational television until the final Carnegie report would be published in late 1966 or early 1967.

10. The U.S. Department of Health, Education, and Welfare (HEW) filed comments encouraging the Commission to consider authorization for nongovernmental, noncommon carrier entities to construct and operate communication satellite facilities. HEW perceived four major advantages from multiple authorizations: (1) Provide the greatest versatility in meeting the broad range of public needs; (2) allow individual entities to make specialized arrangements where necessary; (3) allow for reaching smaller professional or public groups where significant educational gains can be made; and (4) permit the broadest possible continuing experimentation necessary for the quality and variety of programing necessary for (3). HEW noted that not all needs for which private systems could be used involved mass audiences.

The Ford Foundation Proposal

11. In addition to answering the questions posed by the notice of inquiry, the Ford Foundation submitted a model of a private satellite system to provide television transmission for both commercial and noncommercial programing. The proposal calls for creation of a Broadcasters' Nonprofit Service Corp. (BNS), authorized by the Commission to establish communication satellite facilities for transmission of commercial and noncommercial television and radio programing. The corporation would be a joint effort of the commercial and noncommercial institutions engaged in broadcasting. BNS would provide free interconnection for educational stations via satellite and would generate from its commercial users substantial funds (estimated to approximate $30 million a year at first and perhaps twice that much within 10 years) for noncommercial programing, both national and regional. BNS could operate, according to Ford, either as a specialized common carrier or as a cooperative controlled by its commercial, noncommercial and instructional users.

12. In a letter submitting its comments, the Ford Foundation urged that "noncommercial television has unlimited potential, for human welfare and for the quality of American life" and that "nothing is more needed—for television itself as well as for the country—than a first-rate national noncommercial service." Pointing out that it has been in the past the largest single source of funds for noncommercial broadcasting, the Ford Foundation stated that this contribution—though large for it—has been much too small for the needs of noncommercial broadcasting. While the financial needs of educational television are widely recognized, the sources of needed funds for programing have been elusive. The Foundation continued:

"* * * We all want educational television to be properly funded. We do not want the Government to 'pay the piper and call the tune.' We are looking for an answer. And that is what makes the possibilities of satellites so extraordinarily important. Noncommercial television has two great needs: First, to become a true national network, at a cost it can afford, and second, to have the money for programing, at a wholly new level of excellence. Properly used a television satellite can meet both needs. By its natural economic advantage over long landlines, it can effectively eliminate long-distance charges as a determining element in network choices—commercial and noncommercial alike. And if in the case of commercial networks a major share of these savings is passed on to

BEST COPY AVAILABLE

the noncommercial programers, then both problems are on the road to solution, and everyone is better off than he was before. This is not magic, or slight-of-hand. It is a peoples' dividend, earned by the American Nation from its enormous investment in space."

13. It was proposed that the programing fund would consist of two-thirds of the difference in cost to commercial broadcasting between program transmission by BNS and toll line payments to terrestrial carriers, with allowance for continued use of some terrestrial facilities. The Ford Foundation filing contains tables setting forth estimated costs of installation and operation for both an initial BNS-1 system (providing six commercial channels and five noncommercial channels in each of four time zones) and a more expansive BNS-2 system, larger by 20 channels. The Foundation did not contend that BNS would provide all of the funds needed for noncommercial programing or that its particular models were the only way to proceed. Rather than seeking immediate licensing action, the Foundation urged that its proposal be put forth for public comment and that the Commission take no action in the meantime to foreclose this possibility.

C. ISSUANCE OF SUPPLEMENTAL NOTICE OF INQUIRY

14. Reviewing the comments filed August 1, 1966, and cognizant of the needs of all interested parties for the potential use of satellites to provide domestic communication services, the Commission considered it necessary in the public interest to expand the initial scope of this proceeding and to invite comment on the Ford Foundation proposal. In addition, it was found that responses to the initial notice of inquiry were not fully responsive to the technical questions set forth in the initial notice. Accordingly, on October 20, 1966, the Commission adopted a "Supplemental Notice of Inquiry" setting forth the following matters for consideration by interested parties (31 F.R. 13763):

(*a*) The Commission desires to have, to the extent they are available, descriptions, from existing carriers responding to this inquiry, as well as other entities intending to seek authority to provide common carrier services, general or specialized, of their plans for using communication satellite facilities to meet domestic needs; and

(*b*) Whether, as a matter of law, there is any restriction on the Commission's power to authorize any communications common carrier or carriers to construct and operate communications services;

(*c*) Assuming legal authority, under what circumstances should the Commission issue such authorizations, and to whom (one carrier, more than one carrier, two or more carriers jointly) having due regard for, among other things:

(1) The comparative advantages of communication satellites and other communication media in meeting domestic communications needs;

(2) The effects on charges for, and quality and adequacy of, present and future public communications services;

(3) The anticipated volume of domestic communications needs through 1980, and the portion thereof that can and should be satisfied through the use of communication satellite facilities in view of expected technological developments in all media;

(4) The comparative advantages and disadvantages of meeting domestic needs (i) through the facilities of the global system; or (ii) through a separate system or systems;

(5) The effect or impact of any such authorizations upon the policies and goals set forth by the Communications Satellite Act and upon the obligations of the U.S. Government as a signatory to the Executive Agreement Establishing Interim Arrangements for a Global Commercial Communications Satellite System.

(*d*) Whether the type of entity and service contemplated by the Ford Foundation proposal may be licensed under present statutes, and, if not, the type of legislation that would be required.

(1) For the most part, comments filed thus far have not been fully responsive to the technical questions raised in the first notice of inquiry as to the adequacy of existing allocations to the communications satellite service or as to the electromagnetic interference to and from both present and

BEST COPY AVAILABLE

projected operations of the global commercial communication satellite system and the domestic fixed public services sharing the same frequency bands. The latter question is complicated further by the fact that the plenary assembly of the CCIR (Oslo, June 1966), has recommended changes in the technical criteria applicable to the power flux density delivered at the earth's surface from space stations. Therefore, pending resolution of the legal status of the Oslo criteria vis-a-vis those criteria now in the international radio regulations, interested parties, in responding to the questions raised in our prior notice and herein (which include the technical questions explicitly setout in our prior notice) should direct their responses to both the present and Oslo criteria. Additionally, to permit an evaluation of the impact from proposed systems, parties should indicate as fully as they now can the planned positioning of space stations on the equator for the system under consideration if equatorial stationary satellites are involved.

D. FILING OF SUPPLEMENTAL COMMENTS (DECEMBER 1966)

15. By December 16, 1966, the Commission had received supplemental comments from 21 parties, nine of which had not filed previously in this proceeding. Almost all noncarrier entities argued that, as a matter of law, the Commission has power under existing law to authorize entities other than carriers to establish a domestic satellite system. Arinc & ATA, ANPA, the Ford Foundation, NAEB and the three networks urged the Commission not to preclude the authorization of private systems. Comsat, G.T. & E., Hawaiian, the United States Independent Telephone Association (USITA) and Western Union contended that noncarrier entities could not be authorized under existing law; and A.T. & T., Comsat, G.T. & E., Hawaiian, and USITA urged that private systems should not, in any event, be authorized as a matter of policy. With respect to the Ford Foundation's BNS proposal, A.T. & T., Comsat, Hawaiian, USITA, CBS, and NBC urged that additional legislation was required.[1] The Ford Foundation and NAEB commented that clarifying legislation might be desirable, but was not essential.

16. The joint Council on Educational Telecommunications submitted comments supporting favorable consideration by the Commission of some immediate action, such as proposed by Ford, to strengthen and foster development of communication facilities and services dedicated to educational purposes. Lloyd P. Morris, a private citizen filing individually, commented that a major effort must be made at the earliest possible time to improve and accelerate development of local facilities for program production and broadcasting for educational purposes. The National Educational Association and the National Educational Television and Radio Center (NET) supported the Ford proposal and encouraged study of, and immediate effort to resolve problems related to, the structure, activities and financial condition of program production and broadcast facilities of educational organizations and institutions.

17. The National Science Foundation and the National Foundation on the Arts and the Humanities submitted comments supporting consideration of the potential of satellites in educational, cultural and scientific activities and their encouragement and dissemination. They urged that, as a matter of policy, nongovernmental entities other than carriers should be allowed to establish domestic communication facilities to meet private needs, particularly where such needs relate to educational, cultural, and scientific activities.

Proposals for Domestic Systems

18. Four parties—ABC, A.T. & T., Comsat and the Ford Foundation—submitted proposals for domestic satellite systems. In brief, the proposed systems were as follows:

(1) *The ABC Proposal*

19. The ABC proposal, prepared by Hughes Aircraft Co., contemplates a special purpose 24 channel capacity satellite (with one spare in orbit and one in

---

[1] In addition, A.T. & T. challenged the Ford Foundation's estimates of construction and operating costs and questioned whether there would be any savings for noncommercial programming.

BEST COPY AVAILABLE

reserve) to provide three network signals and one ETV signal in each of six time zones (eastern, central, mountain/Pacific, Alaska, Hawaii, and Puerto Rico/Virgin Islands). Each of the three networks would operate earth stations in the vicinity of New York and Los Angeles, which would be capable of transmitting one network signal to each of the six time zones and one ETV signal to the satellite. Receive terminals would be located in each of the television market areas served by one or more networks, each equipped occasionally to transmit one channel to the satellite for special events. There would also be 10 mobile terminals for remote special events originations. The system would operate in the 4 and 6 GHz bands. It is estimated that the initial capital cost would be approximately $80 million, with annual expense in the neighborhood of $17 million, representing annual savings on program transmission costs to the networks of about $11 million. ABC asserts that the networks could voluntarily agree to donate a portion of their savings for ETV program production costs, but could not be required to do so. However, it is willing to make satellite transmission available to noncommercial stations without cost to them.

(2) *The A.T. & T. Proposal*

20. A.T. & T. submitted a comprehensive proposal for an integrated space-earth communications system to meet anticipated growth in long-distance communications requirements through 1980. This system would operate initially in phase I in the 4- and 6-GHz region of the spectrum to facilitate an early establishment, but would in large part shift to 18- and 30-GHz in 1972 in order to obtain the exclusive frequency allocation (estimated to approximate 2800 MHz in the 18 GHz and 30 GHz regions, respectively) believed necessary to full development of a domestic system. The initial system, proposed for operation in 1969, would consist of two geostationary (synchronous) satellites, each with a capacity for 9,600 voice circuits or 12 television channels.[2] There would be two receive-transmit earth stations located in the vicinity (within 10 or 12 miles) of New York City and Los Angeles (with a third satellite and Chicago vicinity earth station to be added in 1970 or 1971) and 73 receive-only earth stations and terrestrial links to meet the TV and ETV needs of 1969.[3]

21. Beginning in 1972 A.T. & T. anticipated use of a new generation of satellites with vastly increased capacity and new capability, in the 4-, 18-, and 30-GHz region of the spectrum, using pulse code modulation (PCM) for voice, and PCM and FM for television transmission. There would be four satellites (two in 1972, a third in 1975, and a fourth in 1976; the latter two replacing the three from the initial phase I), each with capacity for 12 television channels and 30,000 voice circuits. There would also be 26 new earth stations in major metropolitan centers, to be used in conjunction with the 73 receive-only stations from phase I. When fully employed the phase II system would have capacity for 83,000 equivalent voice circuits, 27 television channels and 61 protection and/or occasional television channels. There would be provision for switching capability in the satellites, and for telephone split circuits (one way by satellite and return by terrestrial facilities, to alleviate the time delay problem). Although in phase II all earth station operations would be discontinued in the 6-GHz band, the 4-GHz band would continue to be used for television distribution outside of the northeastern portion of the United States.[4]

22. A.T. & T. estimated that the initial system in 1969 would require an investment of approximately $104 million, with an additional $339 million by 1980. It stated that continuing to meet these requirements through terrestrial facilities

---

[2] A.T. & T. also states that the initial system could have some 3,200 two-way voice circuits, eight full-time television channels, and 12 occasional use television channels.

[3] The A.T. & T. proposal does not contemplate satellite distribution service to the northeastern sector of the United States, where it asserts that economic and interference considerations call for terrestrial facilities only.

[4] Protection against rain attenuation would be provided by space diversity; i.e., each earth complex would consist of two earth stations separated by at least 10 miles and linked by a high-capacity terrestrial system. During sun transit, receiving stations would be interconnected to stations outside the transit area using terrestrial protection facilities. With respect to use of the 17.7–19.3 and 19.4–19.7 GHz bands for transmission of telephone signals (or point-to-point television as distinguished from television distribution channels) from satellite to earth, A.T. & T. estimates that these bands would be divided into one set of 15 channels, spaced 128 MHz and another set of 14 channels, also spaced 128 MHz but located between the first set. The two sets of channels would be used on adjacent antenna beams to reduce interference.

BEST COPY AVAILABLE

alone would require an estimated investment of $183 million in 1969 and $538 million by 1980.[5] A.T. & T. takes the position that any savings should be reflected in the rates charged the general public for common carrier services. It asserts that support of noncommercial television should come from general tax revenues.

(3) *The Comsat Proposal*

23. Comsat also proposed a phased system, to commence in 1969 at 4 and 6 GHz, and later to move into the higher frequencies after a period (perhaps 5 years) of technical research and experimentation in those frequencies. The initial implementation would involve one satellite (12-TV channel capacity), a large antenna facility on each coast and approximately 58 smaller antenna facilities including a few that are mobile. The phase I system would gradually grow to four satellites, six large antenna facilities, and approximately 173 smaller antenna facilities. In the early period, Comsat would include demonstrations and experiments to determine how satellite services can be most effectively and efficiently provided and to permit potential users to obtain knowledge as to practicable service arrangements which will meet their communications needs. In 1973, the system would be augmented by a few more large antennas, approximately 60 smaller antennas, and 20 antennas capable of transmitting in the bands above 10 GHz, if feasible. The third phase, in 1978, would include four satellites of substantially increased capacity and considerable utilization of transmitting and receiving facilities in the frequency bands above 10 GHz.

24. Although estimating that relative annual cost per channel would decline in the later models, with technological advances, Comsat did not set forth precise figures as to estimated costs for the various models. Like A.T. & T., it contends that the multipurpose approach would effect economies over the specialized approach and asserts that "if domestic TV transmission were to be accommodated separately in the early days, general communications would suffer and the largest of all of the immediate 'peoples dividends' from the national space program would be severely prejudiced." According to Comsat, the "large block of the TV requirements supplies the necessary economic base for initiating the multiservice system."

(4) *The Ford Foundation Proposal*

25. The Ford Foundation, in a comprehensive filing comprising three lengthy volumes,[6] proposed two "much improved" systems, BNS–3 and BNS–4, which by comparison with BNS–1 and BNS–2 are "more reliable, more efficient and more economical in their use of the frequency spectrum." By moving to larger satellites lifted by larger launch vehicles (an Atlas Uprated Agena or a Titan 3B Agena), the Ford Foundation's designer was able to propose satellites of greater power and sophistication, each of them carrying 24 channels that can be beamed sharply and powerfully at selected time zones of the United States. The system would include service (omitted from BNS–1 and BNS–2) to Alaska, Hawaii, Puerto Rico and the Virgin Islands. The BNS–3 system would have two satellites, and BNS–4 would have three; either system would have 233 earth terminals of which 10 would be mobile.

26. The Ford Foundation estimates that BNS–3 would have an initial capital cost of $101.3 million and an annual cost of $22.8 million. BNS–4 is estimated to have an initial capital cost of $115.8 million, and an annual cost of $31.8 million. The Ford Foundation states that these cost estimates include all com-

---

[5] A.T. & T. estimated that the crossover point where satellite transmission is economic in comparison to terrestrial facilities is approximately 1,300 miles for non-TV traffic.

[6] Vol. I is addressed to policy and financial issues, vol. II to legal issues, and vol. III to the technical characteristics and costs of BNS–3 and BNS–4, interference problems and adequacy of spectrum space. Included in the Foundation's comments are studies by Joseph A. Pechman, Brookings Institute, on possible sources of tax revenues for noncommercial broadcasting; Prof. Wilbur Schramm, Stanford University, on instructional television; International Business Machines Corp., on potential interference; cost studies by Hughes Aircraft Corp. and Philco-Ford Corp.; and a study, entitled "Communications Rates and Integrated Communications Systems," by Dr. Leland Johnson, indicating how lower costs of satellite transmission would be reflected in rates if there were a common carrier system. Dr. Johnson concludes that the savings are likely to be absorbed and passed on to users, if at all, in amounts too small to be noticed. The Ford Foundation filing also includes a review of noncommercial and instructional television in other countries.

BEST COPY AVAILABLE

mercial, noncommercial and instructional requirements, and necessary microwave and cable links. The present cost of program transmission by terrestrial common carrier facilities is $65 million, expected to increase in the 1970's. The Ford Foundation estimates that by 1970, BNS-3 could replace $55 million (plus $5 to $10 million for a fourth network), leaving potential savings of $31.2 to $36.2 million. These figures represent potential savings, not revenues which the Ford Foundation anticipates will be larger because the economies of satellite transmission will generate business.

27. The Ford Foundation states that BNS-3 and BNS-4, like their predecessors, are still only models open to criticism and subject to improvement. It mentions the possibility of a joint use of facilities, citing TAT IV (*A.T. & T. et al.*, 37 F.C.C. 1151) and stating:

"The alternatives are not either a number of special purpose systems or a single multi-purpose system owned by a common carrier. There are other modes of organization. If there are substantial cost advantages in joint use of some part of the facilities of a television satellite system—on the ground or in space—for telephone and date transmission, there is no reason why that should not be done. Joint use of facilities will undoubtedly require foresight in planning and designing the satellite system to insure flexibility; it will also require ingenuity in developing joint uses or forming joint ownership arrangements. We believe, however, that national economic tradition, the heavy national investment in space, the bright promise of satellite technology and the compelling needs of noncommercial and instructional television obligate us to look beyond traditional responses, as the Commission has done before."

(5) *The Ford Foundation Demonstration Program*

28. The Ford Foundation noted that a number of questions had been raised concerning the feasibility of the Ford Foundation's proposal and Comsat's technical plan and indicated its understanding that serious thought was then being given by others to the possibility of launching a test satellite. The Ford Foundation took the position that a pilot demonstration program should be conducted by the National Aeronautics and Space Administration (NASA) as program manager, although in cooperation with other Federal agencies (including HEW, FCC, DTM, DOD, and the National Bureau of Standards of the Department of Commerce) and all interested private parties including the carriers, the commercial networks, commercial and noncommercial stations, Comsat, the satellite system manufacturers, and the private foundations concerned with public and instructional broadcasting. The Ford Foundation proposed further that, in any event, a pilot demonstration program should not be commenced before April 1968, in order to permit the making of necessary national policy decisions on the issues involved in use of satellites for domestic purposes.

29. The Ford Foundation urged that existing programs and existing spacecraft should be used wherever possible, and modified as required, both for testing and pilot operations. Pointing out that NASA is already engaged in a testing program with its application technology satellite series (ATS) and is therefore in a position to make a swifter beginning, the Ford Foundation asserts that these satellites could be used for interference testing and for early pilot operations of noncommercial and instructional television through satellites. It also claims that interference measurements can begin without satellite through mobile vans and aircraft equipped to make measurements around existing terrestrial facilities and a transportable prototype earth terminal sited near such facilities. If interference measurements and pilot operations cannot ride "piggyback" on an existing program then, the Ford Foundation states, it may be necessary to undertake design of a new satellite, with a 6- to 8-TV channel capability, to transmit signals in two beams, one to the eastern half of the United States and the other to the western half.

30. Whether the "piggyback" approach is used or a new satellite design proves necessary, the Ford Foundation states that the following ground equipment would be useful for conducting pilot operations:

Network terminals with transmit/receive capability	2
Affiliate terminals with transmit/receive capability	6
Mobile terminals with transmit capability	2
Mobile terminals with receive capability	18
Remote schoolhouse terminals with receive capability	20

BEST COPY AVAILABLE

The Ford Foundation contemplates that the first three types of terminals would be primarily used by commercial and noncommercial television networks in the production and distribution of programs, and in testing various network configurations. One of the network affiliated terminals would be used on a time-shared basis to originate instructional programs. The 18 mobile receiving terminals would be used for instructional television purposes to demonstrate satellite program distribution to noncommercial stations and to classrooms for instructional use. The 20 schoolhouse terminals would be so placed as to evaluate a wide-area operational direct-to-school transmission system.[7]

31. The network terminals would be located in New York and Los Angeles, and the affiliated terminals would be used by the networks to feed established regional networks. Each terminal would simultaneously serve all networks, including noncommercial stations. The two mobile transmitting terminals would be used by networks at points of remote program origination, relaying these programs via the satellite. An instructional television demonstration and evaluation program would occupy one or two satellite channels and would require 18 mobile receiving terminals and the 20 schoolhouse terminals. Each mobile terminal would be a complete, self-sufficient television demonstration system consisting of an antenna, a dual-channel receiver, a video distribution system, and approximately 50 color television monitors to be placed in classrooms and auditoriums. Traveling with the terminals would be an operations team consisting of two technicians to install, operate, and maintain the equipment and several trained demonstrators to work with teachers and administrators.

32. The Foundation recognizes that a program of this nature is outside the scope of NASA's presently planned activities and that generous financial support by Congress would be vital. While not prepared to operate or manage anything in this field, Ford would consider how it might contribute to—

Training personnel in noncommercial networking operations through the satellite;

Training teachers and educational administrators in the more effective use of instructional television; and

Making available programs for both noncommercial and instructional television.

E. THE CARNEGIE COMMISSION REPORT

33. In January 1967, Carnegie issued the report to which it had referred in earlier comments filed in this proceeding. Carnegie presented a finding that "a well-financed and well-directed educational television system, substantially larger and far more pervasive and effective than that which now exists in the United States, must be brought into being if the full needs of the American public are to be served. This is the central conclusion of the Commission and all its recommendations are designed accordingly." (Carnegie Report, Bantam, p. 3.) Specifically, Carnegie said:

"(1) We recommend concerted efforts at the Federal, State, and local levels to improve the facilities and to provide for the adequate support of the individual educational television stations and to increase their number.

---

[7] According to the Ford Foundation, all 20 schoolhouse terminals would be placed at schools in a single geographical region. They would remain there for periods of a year or more, in order to integrate the programs they provide into the school curricula. Access to the available channel or channels could be time-shared between State educational entities transmitting programs only to schools in their respective States and a regional body organized to test the feasibility of cooperation on a wider scale.

BEST COPY AVAILABLE

"(2) We recommend that Congress act promptly to authorize and to establish a federally chartered, nonprofit, nongovernmental corporation, to be known as the 'Corporation for Public Television.' The Corporation should be empowered to receive and disburse governmental and private funds in order to extend and improve Public Television programing. The Commission considers the creation of the Corporation fundamental to its proposal and would be most reluctant to recommend the other parts of its plan unless the corporate entity is brought into being.

"(3) We recommend that the Corporation support at least two national production centers, and that it be free to contract with independent producers to prepare Public Television programs for educational television stations.

"(4) We recommend that the Corporation support, by appropriate grants and contracts, the production of Public Television programs by local stations for more-than-local use.

"(5) We recommend that the Corporation on appropriate occasions help support local programing by local stations.

"(6) We recommend that the Corporation provide the educational television system as expeditiously as possible with facilities for live interconnection by conventional means, and that it be enabled to benefit from advances in technology as domestic communications satellites are brought into being. The Commission further recommends that Congress act to permit the granting of preferential rates for educational television for the use of interconnection facilities, or to permit their free use, to the extent that this may not be possible under existing law.

"(7) We recommend that the Corporation encourage and support research and development leading to the improvement of programing and program production.

"(8) We recommend that the Corporation support technical experimentation designed to improve the present television technology.

"(9) We recommend that the Corporation undertake to provide means by which technical, artistic, and specialized personnel may be recruited and trained.

"(10) We recommend that Congress provide the Federal funds required by the Corporation through a manufacturer's excise tax on television sets (beginning at 2 percent and rising to a ceiling of 5 percent). The revenues should be made available to the Corporation through a trust fund.

"(11) We recommend new legislation to enable the Department of Health, Education, and Welfare to provide adequate facilities for stations now in existence, to assist in increasing the number of stations to achieve nationwide coverage, to help support the basic operations of all stations, and to enlarge the support of instructional television programing.

"(12) We recommend that Federal, State, local, and private educational agencies sponsor extensive and innovative studies intended to develop better insights into the use of television in formal and informal education."

Carnegie did not submit any immediate or developed proposal for implementation of an operating satellite system.

F. THE PRESIDENT'S MESSAGE OF FEBRUARY 28, 1967, AND THE PUBLIC BROADCASTING ACT OF 1967

34. The President's 1967 message to Congress on education and health in America indicated the administration's desire to have Congress adopt, at its current session, legislation which would establish a program for implementation of the Carnegie Commission's report. In recommending the establishment of a Corporation for Public Television, the President stated (113 Congressional Record, daily edition S2679):

"One of the Corporation's first tasks should be to study the practicability and the economic advantages of using communication satellites to establish an educational television and radio network. To assist the Corporation, I am directing the Administrator of the National Aeronautics and Space Administration and the

BEST COPY AVAILABLE

Secretary of Health, Education, and Welfare to conduct experiments on the requirements for such a system, and for instructional television, in cooperation with other interested agencies of the Government and their private sector."

Legislation on the matter was promptly introduced in the Senate by Senator Warren G. Magnuson and has since been enacted, Public Broadcasting Act of 1967 (Public Law 90–129, 76 Stat. 65). The Public Broadcasting Act of 1967 provides in section 396(h) that "Nothing in the Communications Act of 1934, as amended, or in any other provision of law shall be construed to prevent United States communications common carriers from rendering free or reduced rate communications interconnection services for non-commercial educational television or radio services, subject to such rules and regulations as the Federal Communications Commission may prescribe."

The Public Broadcasting Corporation has been established.

G. FILING OF REPLY COMMENTS (APRIL 1967)

Comsat Proposes Pilot Demonstration Program

35. On or before April 3, 1967, the Commission received reply comments from 19 parties, four of which were filing in this proceeding for the first time. With one exception, Comsat, there were no notable changes in the positions of the parties which has filed comments or supplemental comments. Comsat presented a new proposal for a pilot demonstration program, which the Corporation considers consistent with the President's message of February 28, 1967, to provide a pilot experience in noncommercial as well as commercial television and in general domestic communication by satellite at the earliest possible time. Specifically, Comsat proposes: (1) To participate in experiments, conducted under government auspices, concerning the practicality and economic advantage of using communications satellites to interconnect educational television and radio stations; (2) to develop under the auspices of the Commission and in conjunction with other appropriate entities, including governmental entities and common carriers, a program to demonstrate communication satellite operations for a variety of services, including commercial and noncommercial broadcasting, voice, and record transmissions; and (3) to expedite the program, under which Comsat would provide the necessary capital, subject to Commission approval, without prejudice to the question of ultimate ownership, construct a minimum number of earth stations, and procure appropriate satellite launches to provide one television channel free in each of two time zones for educational television networking, with additional capacity for experiments and demonstrations to prove and exhibit potential advantages of satellite services for noncommercial television and radio as well as for other services. Capacity in the model would also be available for commercial television transmission and transcontinental common carrier service, to provide a financial foundation for the model. The demonstration facilities would be so designed that they would be absorbed eventually in a long term complex for the furnishing of commercial service after the termination of their use for demonstration purposes.

36. Comsat proposed that the Commission adopt a statement of interim policy approving the principles of a pilot demonstration program set out in such filing; call a conference of appropriate interested persons and entities (interested carriers, educational and commercial broadcasters, HEW, NASA, DTM, NET, the Ford Foundation, etc.) to plan such a program; and subsequently, on the Commission's own motion or on application by a party, take action to establish a pilot demonstration model system. Comsat noted that all technical proposals made by the parties contemplated certain common minimum requirements needed in the long-run for a single multipurpose system or for one or more dedicated systems. Its model system would be designed to permit eventual absorption in a long-term complex for commercial service. It described the initial objective of the program as making noncommercial television and general communications by satellite available throughout the Pacific and Rocky Mountains time zones, with direct access from New York. Commercial television and general communications services would be accommodated at commercial rates, and one television channel in each time zone would be made available without charge for educational broadcasting. Capacity would be provided for experiments, particular

BEST COPY AVAILABLE

demonstrations, and long-distance services. Comsat urged that steps now be taken to assure that needed facilities will be available for experiments, demonstrations, and the described services.

37. On July 26, 1967, Comsat elaborated on its proposal in a response to a letter from the Commission. The Comsat pilot program, contemplated to be completed during the 2 years 1970–71, would use two satellites, each with a 5-year life, in synchronous orbit between 70° and 120° W. longitude, tentatively 97° and 103° W. longitude. Their coverage would include parts of Canada and Mexico as well as the mainland United States. Radiation outside the United States would not (according to Comsat) cause harmful interference with terrestrial radio facilities. The satellites each would have a capacity of 12 color television channels, or 21,600 voice channels when used with 85-foot antennas, or 9,600 voice channels when used with 42-foot antennas. Television, voice, data, telegraph, etc., could be simultaneously transmitted. Normally, each satellite would be used for both full-time and occasional service, but if one failed, the other could handle all full-time service needs. The satellite would transmit at 3700-4200 MHz and receive in the 5925- to 6475-MHz band.

38. Comsat proposes a send/receive earth station near New York City and another near Los Angeles, each with two 85-foot antennas, each antenna being capable of using the full capacity of one satellite. It proposes two send/receive earth stations, each with a 42-foot antenna, one in the northwest and one in the southeast, which can transmit and receive multipoint message channels and color television. The proposal also calls for 30 receive only stations, with 25- to 32-foot antennas, in the Pacific and Rocky Mountains time zones. These zones are considered by Comsat as best suited for demonstrating the distribution capabilities of satellites, because of large distances, sparse population, and limited available terrestrial facilities.

39. This system configuration is based on Comsat's estimate of current demand, as derived from its talks with certain major users; it states, however, that no facility would be constructed without reasonable assurance of economic use. Total investment is estimated at $57,700,000, of which $37,220,000 would be recovered over the 5-year period 1970–74. (Comsat anticipates, however, that the pilot program will have before then justified a follow-on program for wide area coverage.) Total revenue requirements, then, including an annual operating cost of $4,070,000 and 12-percent return on investment after taxes, start at $24,485,000 in 1970 and decline to $17,312,000 in 1974 (with a declining investment). The requirements over the entire 5 years are $104,428,000.

40. Comsat recognizes that all costs could not be recovered in the 5-year period, on the assumption that this would require noncompetitive pricing. However, it proposes a multiservice system, with each service charge being related to its costs so far as possible. There would, however, be capacity associated with two noncommercial television channels offered without charge. To the extent that costs are not recovered in the 2-year pilot program, Comsat proposes that they be recovered in later years.

41. Comsat is willing to finance, own, and operate the earth stations itself, or to share in a divided ownership with appropriate carriers. Satellite ownership and operation would be in conformity with international obligations under the definitive Intelsat arrangements now being negotiated.

H. SUPPLEMENTAL COMMENTS ON COMSAT'S PILOT PROPOSAL (SEPTEMBER 1967)

42. Since Comsat's proposed pilot demonstration program was presented for the first time during the final round of comments submitted on or before April 3, 1967, no other parties to the proceeding were provided an opportunity to study and respond to the proposal or to offer counterproposals. On August 14, 1967, the Ford Foundation filed with the Commission a petition for leave to file further comments on the Comsat proposal submitted March 31, 1967, and elaborated in July 1967. The Commission, desiring to assure full consideration and discussion of the relevant issues in the Comsat proposal, issued an order on August 29, 1967, inviting further comments from all interested parties on the Comsat proposal. Deadline for filing of such comments was set for September 18, 1967.

43. Twelve parties filed comments in response to the Commission's order. A.T. & T., Hawaiian Telephone Co., and G.T. & E. favored early implementation

BEST COPY AVAILABLE

of Comsat's pilot program. A.T. & T. urged further that the earth stations be owned by the common carriers utilizing them to provide service to the public. Hawaiian maintained that users of the satellite system should be limited to the terrestrial carriers in all ordinary circumstances. ANPA, CBS, and Western Union Telegraph also supported Comsat's proposal, but cautioned against permitting Comsat to obtain a de facto position of dominance so as to prejudge a considered decision on the various issues pending before the Commission in this proceeding.

44. While agreeing on the desirability of a test program, NBC, ARINC and ATA questioned the advisability of an immediate acceptance of Comsat's proposal. ARINC and ATA felt that authorization would give Comsat a substantial foot in the door toward ultimate ownership of the system and questioned: (1) Whether Comsat is legally qualified to provide domestic service, and (2) whether Comsat's capital resources are not precommitted exclusively to the global system. NBC urged that a conference of interested Government and industry parties precede any authorization, in order to give the Commission a more complete and considered basis than is now available on which to authorize a test program.

45. ABC and the Ford Foundation opposed the Comsat proposal. Both saw authorization as giving Comsat the inside track toward ultimate ownership and supported instead, a test program conducted by a more disinterested entity, such as NASA. Ford contended further that acceptance of the Comsat proposal would be an untimely prejudgment of the issues now being considered by the President's Task Force on Communications Policy (see infra, sec. J), viz, whether a domestic satellite system should be generalized or specialized, and whether there should be more than one system. Ford also maintained that the Comsat proposal makes insufficient provision for the possibilities of satellite communications in the field of public television, both as a provider of free interconnection and as a source of protected program funds.

46. Ford further claimed in its September 1967 filing that there are other technical tests, less expensive and less time-consuming than the Comsat program, that can usefully be undertaken before a full-scale program costing tens of millions of dollars is warranted. Appended to this filing are two studies conducted by Stanford Research Institute (SRI), and Hammet & Edison (Hammet), setting forth a number of tests which they consider useful. Among other things, Hammet states that it appears feasible to distribute television programing by satellite in the bands now allocated to the Television Auxiliary Broadcast Service without disrupting present use of these frequencies, and that the use of these bands would reduce congestion in the common carrier bands and result in considerably more efficient use of the spectrum than that now planned in the 4 and 6 GHz bands.

47. ABC Television Affiliates and CBS Television Network Affiliates, both filing for the first time in this proceeding, urged that broadcast stations should be allowed, individually or in groups, to own the ground receiving equipment necessary to provide television interconnection service to them by satellite.

I. COMSAT REPLY

48. On September 20, 1967, Comsat filed a response to the comments on its proposed pilot program, with a covering letter addressed to the Ford comments. Comsat observed that Ford's concern with funding public television leads it to underemphasize domestic communications in general, which the Comsat proposal would meet through a multipurpose system, and so give each experience in economic use of satellite and earth service facilities. Though Comsat notes it has provided for preferential rates to noncommercial broadcasting, it says it is not willing to make the networks a captive treasury for public television.

J. OTHER PERTINENT BACKGROUND

49. The President's message of August 14, 1967, transmitting recommendations relative to world communications, states, inter alia, with respect to domestic communications satellite systems (H.R. Doc. No. 157, 90th Cong., 1st Sess., p. 6):

> "The space segment of a communications satellite system is international by its very nature.
>
> "A synchronous satellite occupies a permanent orbital position in the international domain of outer space.

BEST COPY AVAILABLE

"All satellites radiate electro-magnetic energy potentially capable of interference with other communications systems.

"All satellites use the internationally regulated frequency spectrum.

"In view of the international nature of satellite communications and our commitments under the Intelsat agreement of 1964, we should take no action in the establishment of a domestic system which is incompatible with our support of a global system.

"This does not mean that the United States—or any nation—will give up vital sovereignty over domestic communications. The flow of satellite communications—both domestic and international—is to and from ground stations owned by the individual nation or its representative. Each country will have to determine for itself whether it wants to use communications satellites for domestic purposes. It must be prepared to bear the expense of such satellite use, just as it will derive any revenues.

"It is the space segment—not the ground station—that is of legitimate international concern. How should a nation utilize satellites for domestic communications purposes?

"There are several possible choices:

"A nation can lease circuits from an international Intelsat satellite.

"It could elect to operate a separate satellite for its own domestic use.

"It could join with neighboring countries to operate a separate satellite."

50. The President further announced the appointment of a task force on communication policy to study and report on the following questions within 1 year (id. at pps. 8–9):

"Are we making the best use of the electro-magnetic frequency spectrum?

"How soon will a domestic satellite system be economically feasible?

"Should a domestic satellite system be general purpose or specialized, and should there be more than one system?

"How will these and other developments affect Comsat and the international communication carriers?"

The final report of that task force, dated December 7, 1968, concluded, inter alia, that satellites may play a significant role in meeting domestic requirements, but that it would be premature to establish full-scale domestic satellite operations at this time. The task force recommended that the Commission establish a pilot program for a 2- to 3-year period along the following lines:

(*a*) The pilot system should be multipurpose;

(*b*) Comsat should own the space segment as trustee and serve as overall manager of the system;

(*c*) Comsat, terrestrial common carriers and prospective users of wideband services should be eligible to invest as trustees in the ground environment;

(*b*) Comsat should own the space segment as trustee and serve as overall potential users;

(*e*) The pilot should employ appropriate advanced technology to obtain technical and operation data, including interference measurements and sharing criteria, channel multiplication by spectrum reuse, and service to noncontiguous areas of the United States;

(*f*) The pilot should offer free satellite channels for noncommercial and instructional television; and

(*g*) The pilot program should be consistent with U.S. international commitments and appropriately related to Intelsat.

51. The Inter-Governmental Agreement and Special Agreement of 1964 (TIAS No. 5646) establishing interim arrangements for the global commercial communications satellite system (Intelsat) do not treat the matter of domestic satellite systems. Article IX of the agreement provides for the negotiation of definitive arrangements for Intelsat in 1969. The U.S. proposal for such definitive arrangements contains a provision for the establishment of separate satellites by a member of Intelsat to meet its domestic needs. The proposal states, however, that "clearly the space segment of even a domestic satellite system is a matter of legitimate international concern, and no action should be taken in the establishment of a domestic system which is incompatible with the global Intelsat system." The proposal further states that in order that legitimate international concerns would be fully protected, the governing body of Intelsat would have to decide prior to the establishment of a domestic satellite system that—

BEST COPY AVAILABLE

(*a*) The establishment of such facilities would be consistent with Intelsat's proposed use of the frequency spectrum and orbital space, and

(*b*) The proposed mechanism and techniques for control of these satellites were adequate, and the radiation emitted from the satellites would not cause harmful interference.

In February and March 1969, an international conference was held in Washington, D.C., to begin negotiations on definitive arrangements, and was reconvened to continue such negotiations in February 1970.

K. THE GE PROPOSAL

52. On February 19, 1969, General Electric Co. (GE) sought leave to supplement its original filings with additional comments setting forth its present view of new and expanded communications services that might appropriately be provided via satellite. In the interest of a full record that might be of assistance in arriving at policy determinations, the Commission accepted the filing and accorded parties to the proceeding an opportunity for comment. GE states that in view of uncertainties as to the structuring of a domestic satellite system, it cannot in the exercise of a prudent business judgment undertake commitments of an investment or operational nature in the system it is proposing. Rather, it is making the conclusions drawn from its studies and research available in an effort to assist the Commission and stands ready to provide further technical and other data.

53. The GE proposal rests on its conclusion that "introduction of satellite communication technology into our domestic communications system can provide the means for a revitalization of the business usage of the record communications system in the United States," that it "offers a unique opportunity for the achievement of a repeatedly recognized basic legislative and administrative policy objective, i.e., the development of a balanced national communications system including not only the excellent voice switched network system provided by the Bell System but also a viable and effective truly competitive record communications alternative." While stating that consideration should be given to authorizing the proposed system to existing communications common carriers, GE suggests that a possibility equally worthy of a serious consideration would be authorization of an entirely new common carrier entity for the purposes it describes—"one not deterred by existing capital or other commitments in the present common carrier system."

54. GE's proposed system and services concentrate on areas of data and other record message point-to-point transmission that would not require the availability of complex switching arrangements. The basic array of proposed services is subdivided as follows:

- (1) Multiple access digital services (MADS).
  - (*a*) Record services.
  - (*b*) Remote access computer services (RACS).
- (2) Multiple access video services (MAVS).

55. With respect to MADS-record services, GE states that record communications of the nature of Telex, TWX, and private wire systems could be provided much more economically via satellite, by eliminating most of the present hierarchy of switching on the terrestrial network, and thus would become available to a far greater number of users. It also contemplates a service designated as "Telemail" for business-to-business "transaction" mail (allegedly about 17 percent of all mail), which would ultimately be provided at rates comparable to postal service, but with instant delivery.

56. In the area of remote access computer services (RACS), GE states that a key service of the proposed system would be the provision of communications needed for computer-to-computer and computer-to-individual user purposes. This would involve not only communications for time-sharing computer facilities, but also provide communications capabilities for many other types of computer uses that do not involve time sharing. GE also asserts that the availability of nationwide metropolitan area access to time-sharing centers, regardless of physical location, should increase the practicability of nationwide data banks or library services provided from very large storage facilities in one location.

57. The proposed multiple access video services (MAVS) contemplates random assembled video networks for use by business, professional, government, educa-

BEST COPY AVAILABLE

tional and social organizations. A primary objective of the MAVS service would be to provide mobile ground stations for transmission, reception, or both. It is asserted that this would facilitate meetings, conferences, seminars and other face-to-face confrontations and save the time now spent on travel. The service provided could be simplex, half-duplex, or full-duplex video with duplex audio. GE foresees two additional video services: (1) A public video exchange (PVX) to meet the requirements of any person or group that are insufficient to require a dedicated facility, in which case the subscriber would be required to go to the public studio; and (2) a private video exchange for customers with large usage (e.g., the central office and a remote production facility of a large corporation, a central university and its extension facilities, State governments and their regional or county centers, etc.) in which case the ground facility would be located at the subscribers premises.

58. GE further states that the demands for data and video services would not utilize the full satellite capacity, and that extra transponders would be available for use by common carriers (such as telephone carriers), and private network users (e.g., broadcast networks, airline entities, etc.). It states that control of this portion of the satellite facilities would be with the user of these transponders, who would provide the related ground facilities.

59. The GE filing sets forth in some detail the estimated market potential and rates for the various proposed services, the basic technical and operational mode of the proposed system, technical characteristics of the satellite and other equipment, general system parameters, and the estimated cost structure. Rather than attempting to summarize GE's discussion and charts here, we refer interested persons to the GE filing itself. We do note, however, that GE contemplates use of frequencies in the 4- and 6-GHz bands; digital transmission; the use of one computerized "routing center," as director of systems traffic for all ground facilities, which would perform the channel assignment, billing, TT. & C., and system diagnostic maintenance functions; the standard use of 30-foot antennas in the proposed 175 earth stations; and the use of CATV cable and/or microwave links, as well as local telephone loops, to provide local interconnection with the satellite system facilities.

60. The estimated system costs for full implementation by 1980 are calculated to amount to approximately $321 million. This includes initial and continuing research and development costs of both satellite and earth facilities, and procurement of five satellites (assumed 5-year life) and boosters. The largest single item of investment would be earth facilities, including 175 earth stations, one routing center and other administrative facilities. Personnel requirement estimates range from 1,300 people at the time of initial satellite launch to approximately 4,700 for full operational capability in 1980.

61. GE argues against authorization of a pilot or interim system, claiming that the uncertainty would prejudice its ability effectively and aggressively to advance new markets. It asserts that sound business judgments would require a reasonable degree of certainty concerning continuation of the system that would only be associated with a more permanent system. GE states that the justification for a pilot would depend primarily on an assumption that there are major technical uncertainties, which is contrary to the established technical feasibility of synchronous satellites for the purposes it advances.

62. Comments on the GE proposal were filed by 12 parties on or before April 14, 1969. In general, noncarrier parties either commented favorably or took no position on the GE proposal, but requested prompt action by the Commission to encourage rapid development of some form of domestic satellite program. ABC states that the GE proposal does not exclude an additional, separate broadcaster system and urges expeditious authorization of such a system. While NBC believes a separate broadcaster system to be best, it would also support another system that could better serve the needs of program transmission users. It further urges that a demonstration program, utilizing existing types of equipment such as ATS or Intelsat I and II satellites and transportable earth terminals, should commence as soon as possible. The NAM considers the GE proposal to be an excellent contribution. Aerospace Industries claims that the needs of aerospace companies are not now being met promptly and efficiently, and that an expansion of existing facilities is urgently needed. It asserts that any of the domestic satellite proposals in this docket would be a welcome addition. Con Sumers, Inc., and TVC of California, Inc., commenting for the first

BEST COPY AVAILABLE

time in this proceeding, state that domestic satellite facilities could be used for other video services (in addition to those proposed by GE) which would require encoding and decoding to ensure that the communication goes only to subscribers, e.g., subscription television and subscription services to the medical profession and small businessmen. It further claims that the prescription of uniform standards for transmission and reception equipment is essential if this potential is to be realized.

63. Common carrier parties were divided in their views on the GE proposal. Comsat adhered to the position that its pilot proposal is best and must include the network television market to be viable. However, Comsat states that if there should be customer demand for the types of services proposed by GE, these requirements could be accommodated in the pilot plan or at some later date. ITT Worldcom commends the GE proposal, but states that the services should be provided on a common carrier basis, by existing carriers, and that decisions as to ownership would be premature prior to formal applications containing adequate data. MCI approves of the GE proposal for new entry and expresses its continuing interest. WUI shares GE's concern that a domestic satellite system be utilized to its fullest potential, and urges that this would be best accomplished by a single multipurpose system, owned by existing carriers—including Comsat and international carriers who would use a domestic system between gateway centers and satellite earth stations or cable terminals.

64. WU, G.T. & E., and A.T. & T. were critical of the GE proposal. All three assert that the proposed services are being, or could be, provided by terrestrial carriers and that the alleged cost advantages of satellite are unsupported. In the latter connection, they claim that GE's estimated costs are understated and fail to take account of local distribution and terminal costs. It is further urged that GE overemphasizes elimination of terrestrial switching steps, since terrestrial systems utilize direct routes where there is adequate volume and use switching to save costs between low-volume points and for alternate routing. A.T. & T. claims that the GE traffic projections and estimated revenues are unrealistic and overly optimistic, in part because a preponderance of traffic would be short haul and much would never leave the area served by a single earth station. A.T. & T. further states that GE does not provide for restoration of facilities over alternative paths; if an earth station failed, the only alternative would be terrestrial facilities to another earth station and in the event of outage at the routing center, the whole system would be out. A.T. & T. concludes that the GE proposal in its present form is too inadequate and incomplete to provide a basis for affirmative action. G.T. & E. states that the concepts advanced are interesting and worthy of discussion, but that this proceeding is not an appropriate context.

65. More generally as a matter of policy, WU urges that the proposal for a new record carrier is not sound. It further states that a pilot is desirable to test economic factors, because the uncertainties are not technical, but economic. A.T. & T. argues that the GE proposal rests on an erroneous assumption of a national policy in favor of competition in the common carrier field. It asserts that separate systems for voice and record would be technically unsound, economically wrong, and contrary to the interest of communications users in general.

66. On May 15, 1969, the Postmaster General filed comments on the "telemail" aspect of the GE proposal and its relationship to potential electronic transmission of domestic communications presently carried in the U.S. mail. It is stated that conceivably, upon ultimate refinement of the concept, all letter mail, or approximately 56.8 percent of all mail pieces, could be supplanted by a telemail system and that such a diversion would represent approximately 55 percent of revenues realized from domestic mail. The Postmaster General requested the Commission to consider the potential impact its decision might have upon the postal system, and to fashion its decision so that the Post Office Department would not be precluded from acquiring its own electronic communication system at some future date or be restricted to dealing with a sole licensee.

BEST COPY AVAILABLE

Appendix C Flanigan Memorandum
22 F.C.C.2d 86, 125 (1970)

THE WHITE HOUSE,
Washington, January 23, 1970.

MEMORANDUM FOR: HON. DEAN BURCH, CHAIRMAN, FEDERAL COMMUNICATIONS COMMISSION

Federal policy on domestic satellite communications has been long delayed. The administration is concerned that the delay not be prolonged and that the policies adopted reflect all important dimensions of the public interest, including the international aspects of geostationary orbital and radio resources. Based on our review of relevant technical, economic, and public interest considerations, the administration offers the following comments and recommendations to the Commission.

PUBLIC POLICY OBJECTIVES

In telecommunications, the Government's responsibility to safeguard and promote the public interest involves primarily the encouragement of reliable communications services for public, business, and Government use at reasonable rates and the assurance of a healthy environment for continuing innovations in services and technology. This general goal must, of course, be made more specific for particular policy issues. In our review of the domestic satellite issue, we have concentrated on the following objectives:

—Assuring full and timely benefit to the public of the economic and service potential of satellite technology.
—Insuring maximum learning about the possibilities for satellite services.
—Minimizing unnecessary regulatory and administrative impediments to technological and market development by the private sector.
—Encouraging more vigorous innovation and flexibility within the communications industry to meet a constantly changing spectrum of public and private communications requirements at reasonable rates.
—Discouraging anticompetitive practices—such as discriminatory pricing or interconnection practices and cross-subsidization between public monopoly and private service offerings—that inhibit the growth of a healthy structure in communications and related industries.
—Assuring that national security and emergency preparedness needs are met.

THE TECHNICAL FRAMEWORK

The establishment and operation of domestic satellite communications facilities is technically feasible within the present state of the art, and readily foreseeable technological advances will further enhance this capability. Technical considerations place no serious constraints on policies governing the ownership or mode of operation (specialized or multipurpose) of domestic satellite communications facilities. These technical considerations, though of great importance in the detailed engineering, operations, and economics of specific systems, can be dealt with effectively under any reasonably foreseeable ownership arrangements.

The issue of radio resource scarcity for satellite communications has been overstated to a significant degree. While the communications capacity of this resource is finite, the ability to accommodate additional radio services is greatly expandable through administrative, technological, and operational innovation. Both earth station and satellite design standards can be varied to assure adequate orbital capacity for both immediate requirements and likely near-term growth. Long-term growth can be accommodated through further refinement or additional frequency allocations, whichever is most economic.

Since some of the orbital locations and associated spectrum usage of interest for U.S. domestic satellites might also be potentially useful to other western hemisphere nations, a question of U.S. monopolization could conceivably arise. However, even 10 to 12 U.S. domestic satellites (a high estimate of likely early system development) would represent only a small fraction of the number which could be accommodated for Western Hemisphere use with the current state of the art. Therefore, orbital capacity is not expected to be a problem at this time. As demand for satellite communication expands, it may become necessary to evolve additional international coordinating mechanisms; but this would likely involve the establishment of appropriate technical standards rather than the rationing of orbital positions. This is expected to be a subject for discussion at the 1971 World Administrative Radio Conference.

BEST COPY AVAILABLE

C2

THE ECONOMIC FRAMEWORK

The most immediate potential for domestic satellite communications seems to lie in long distance specialized transmission services—such as one-way distribution of radio and television programs or two-way exchange of high-speed data or other wideband signals among thinly dispersed users. Common carriers have informed us that satellites do not appear economic at present for the routine transmission of public-message traffic.

For the foreseeable future, satellite communications systems will require large initial investments, careful technical and economic planning, and complex technical management capabilities. The extensive, reliable, and low-cost terrestrial communications network already established in the United States makes domestic satellite systems competitive only where their unique capabilities offer significant advantages over terrestrial transmission. We, therefore, expect the initial number of potential offerers of domestic satellite services to be small.

In the absence of clear economies of scale and overriding public interest considerations to the contrary, the American economy has relied on competitive private enterprise rather than regulated monopoly to assure technical and market innovation, long-run optimum use of resources, and industry flexibility. These are all conditions this Nation has found to encourage higher-quality, lower-cost services responsive to consumer demand.

At this stage of domestic satellite planning, it is not possible to identify major economies of scale. Rather, it appears that a diversity of multiple-satellite systems as well as multiple-earth stations will be required to provide a full range of domestic services.

Further, we find no public interest grounds for establishing a monopoly in domestic satellite communications. The general public is not a direct user of such services. The provision of specialized transmission services and the carriage of bulk message traffic are quite different in character from the provision of switched public message (telephone) service upon which much of our monopoly theory of telecommunications regulation is based. There is no reason to expect that competition here would do other than to encourage new or lower-cost services, the benefits of which would indirectly accrue to the public. Competition in the offering of satellite services appears to hold forth greater benefit to the economy and the public than would a single chosen instrument.

Detailed regulation of service rates and commercial rates of return are similarly predicated on natural monopoly conditions that should not exist with domestic satellite communications in the immediate future. Not only is competitive entry possible, but terrestrial communications pricing would act as an upper limit on prices chargeable for most satellite services. In these circumstances, competitive pressure, rather than regulatory constraints, should be permitted to limit rates for specialized services via domestic satellites.

The historical development of telecommunications policy, regulation, and industry structure has resulted in a blurred distinction between public and private interests. A confusing patchwork of cross-subsidization between public message and specialized service offerings has become the norm rather than the exception. Therefore, it is possible that satellite services could, through cost-reducing innovation and competition, cause some existing services now surviving on a cross-subsidized basis to become uneconomic. Even if the benefits of such cross-subsidization accrue to the public users rather than to private service offerings, however, there seems to be no merit in protecting suppliers of such services from fair competition. The primary impact of such competition should be the provision of those services through lower cost alternatives. Should such competition result in curtailment of some public services that are necessary as a matter of public policy, however, a direct public subsidy would in most cases be less costly to the public than forced cross-subsidization and restraint of competition.

RECOMMENDATION

Government policy should encourage and facilitate the development of commercial domestic satellite communications systems to the extent that private enterprise finds them economically and operationally feasible. We find no reason to call for the immediate establishment of a domestic satellite system as a matter of public policy. Government should not seek to promote uneconomic sys-

BEST COPY AVAILABLE

C3

tems or to dictate ownership arrangements; nor should coordinated planning or operation of such facilities be required except as essential to avoid harmful radio interference.

Subject to appropriate conditions to preclude harmful interference and anti-competitive practices, any financially qualified public or private entity, including Government corporations, should be permitted to establish and operate domestic satellite facilities for its own needs; join with related entities in common user, cooperative facilities; establish facilities for lease to prospective users; or establish facilities to be used in providing specialized carrier services on a competitive basis. Within the constraints outlined below, common carriers should be free to establish facilities for either switched public message or specialized services, or both.

The number or classes of potential offerers of satellite services should not be limited arbitrarily. Nor should there be any a priori ranking of potential types of systems (common carrier versus specialized carrier versus private; or satellite versus terrestrial). Only in the event that specific applications pose immediate and irreconcilable conflict in the use of radio and orbital resources would an a priori public-interest exclusion of proposals be warranted. In particular, the potential economic impact of private or common-user satellite systems on terrestrial common carriers or specialized carriers should not be a factor in the authorization of such systems.

All prospective entrants should be afforded equal opportunity to establish and operate domestic satellite communications facilities by adoption of the following guidelines:

(1) Facilities to be established by independent entities for their own private use should be required to demonstrate only the financial and technical qualifications to implement their system proposals. There is no valid public-interest requirement in such cases to require a showing of economic viability or optimization, nor should the potential economic impact of such operations on common or specialized carriers be a factor in the authorization of such facilities.

(2) Facilities to be established as part of a common-user cooperative system should be authorized in accord with the same principles as for fully independent facilities. However, to avoid restraints on competition, the opportunity should be made available for all potential users of similar services to participate without discrimination in such cooperatives as a condition of their authorization.

(3) Facilities to be used by specialized carriers (i.e., carriers having no monopoly over switched public message services) should be authorized under essentially the same terms and conditions as private or common-user facilities. Furthermore, such specialized carriers should not be constrained to serve as a carrier's carrier nor to share ownership of space or earth station facilities with other carriers. We also urge the Commission to allow competition to limit the rates charged for specialized services via satellite. Specialized carriers should, however, be required to serve similar users at equal rates and on a nondiscriminatory basis.

(4) Facilities to be used by common carriers solely for the transmission of switched public message services should be authorized under the same terms and conditions that apply for terrestrial radio facilities. However, facilities to be used by such carriers in the transmission of specialized message services should be authorized only after a determination by the Commission on each application, based on public evidentiary hearings, that no cross-subsidization between monopoly public message and specialized services would take place in the development, manufacture, installation, or operation of such facilities. This should not be interpreted, however, to preclude the legitimate economies of joint-use facilities.

(5) The use of leased facilities (satellite and/or earth stations) should be authorized under the same terms and conditions as owned facilities, with the responsibility for adherence to these conditions resting with the lessee. Rate-regulated carriers should be permitted to include a portion of the lease costs of such facilities in their rate base.

(6) Local communications common carriers should be required to provide leased interconnection services for user access to earth stations at reasonable rates and without discrimination.

(7) Potential harmful interference between satellite systems and terrestrial installations should be resolved by the Commission according to established

BEST COPY AVAILABLE

procedures. Satellite operating entities should have equal status with terrestrial users in interference problems and in access to the radio spectrum. To accommodate new systems or services, the Commission should affirm its authority to modify or rescind, where appropriate, the operating rights of established spectrum users (satellite or terrestrial) where this would not significantly impair the quality of service or impose undue economic burdens; we believe the Commission should require compensation of the established users to be paid by the new entrant in such situations.

(8) The Commission may wish to establish a minimum acceptable earth station diameter, such as 30 feet, in order to accommodate an adequate number of initial U.S. domestic satellites in the 4- and 6-GHz spectrum allocations without excessive use of orbital resources. Although it is very unlikely that the number of satellites proposed during the initial filing period will approach the limit such a standard would impose, the standard should in that event be raised. Conversely, if applications were well below this number, and a reasonable case were made on economic and operational grounds, the standard could be relaxed in specific cases. To the extent possible, within the state of the art, the satellite antenna radiation pattern should encompass only the specific land areas to be served.

In a time of rapid technological, economic, and social change, we would be ill-advised to adopt a definitive policy without the flexibility for future review or to adopt an overly restrictive policy simply because of our inability to predict future developments. We therefore recommend that the above policies be adopted on an interim basis, such as 3 to 5 years, to permit vigorous exploration and development of satellite service possibilities. During this period, the Commission should monitor the industry structure, service offerings, and rates to determine if natural monopoly or other conditions are developing that suggest more restrictive entry conditions or warrant direct rate regulation for specialized satellite services. At the end of the interim period, a full review of the policy and industry structure should be made.

It is most important that the establishment and operation of domestic satellite communications facilities be consistent with our obligations and commitments to Intelsat and the International Telecommunications Union, with other foreign policy considerations, and with national security communications requirements. With respect to Intelsat, it is particularly important that domestic systems not threaten the operational integrity or economic viability of the global services provided through that system. It is also important that provision be made for use of domestic satellite services by national security and emergency preparedness agencies when apppriate. We are satisfied that domestic satellite communications facilities authorized in accordance with the preceding recommendations will meet all these conditions. We further see no reason why the Communications Satellite Corp., established by Congress as the chosen instrument for U.S. participation in Intelsat, should not be permitted to compete for domestic satellite service on an equal basis under the above guidelines.

PETER FLANIGAN,
Assistant to the President.

BEST COPY AVAILABLE

CHAPTER FOUR

METEOROLOGICAL SATELLITES

I. INTRODUCTION

First by the use of kites and balloons, later by the use of instrumented airplanes, the science of meteorology has developed in large part by observing the Earth's turbulent atmosphere from ever higher altitudes. This progression led in the early space age to the development of orbiting weather satellites.

The first successes in photographing the Earth from space came soon after World War II. Some of the V-2 rockets launched from White Sands, New Mexico in the late 1940's were equipped with cameras that photographed portions of the Earth below in order to help determine the rocket's altitude. Cloud patterns naturally appeared in these pictures, as they did in later Aerobee rocket tests (1954), Project Hugo tests (1958)[1] and particularly clearly in an Atlas rocket test on August 24, 1959. The significance of these high-altitude pictures was not lost on meteorologists.

Scientific feasibility reports and discussions of the possible meteorological uses of orbiting satellites were underway as early as 1951 at various branches of the Department of Defense, at the offices of their contractors, and at the U.S. Weather Bureau.[2] Planning of satellites with meteorological applications continued throughout the 1950's.

Vanguard 2, launched on February 7, 1959, was intended to provide cloud cover data, but precession (wobbling) prevented the acquisition of data from what would have been the world's first weather satellite. In the same year Explorer VI (launched August 7, 1959) became the first satellite to return usable photos of the Earth, and Explorer VII (launched October 13, 1959) successfully carried an instrument to measure the Earth's budget of incoming and outgoing energy. Other versions of this nonphotographic experiment flew on later TIROS and Nimbus satellites.

In the spring of 1958, the Defense Department's Advanced Research Projects Agency [ARPA] called for a committee formed from representatives of the U.S. Weather Bureau, Army, Navy, Air Force, the National Advisory Committee on Aeronautics [NACA], (later to become [NASA]) and the Rand Corporation with the goal of developing a meteorological satellite system. This project, transferred to NASA in April 1959, led to the building and launch of the Nation's first weather satellite, TIROS 1, in 1960.

---

[1] Widger, William K. "Meteorological Satellites." New York. Holt, Rinehart & Winston. 1966. p. 47

[2] Greenfield, S. M. and Kellogg, W. W. "Inquiry into the Feasibility of Weather Reconnaissance from a Satellite Vehicle." Rand Corp. report No. R-365. August 1960 (Unclassified edition of Rand report No. R-218, issued 1951). (Reference from Widger, op. cit. p. 289)

Since then, the U.S. civilian meteorological satellite program has been a succession of experimental satellites followed by operational systems. NASA is in charge of the experimental programs, while the Department of Commerce (though the National Oceanic and Atmospheric Administration [NOAA], and previously through the Environmental Satellite Services Administration [ESSA]) is in charge of the operational systems.

There have been five NASA experimental meteorological satellite programs to date, with launches in the years indicated: TIROS (1960–1965), Nimbus (1964–1978), TIROS M/ITOS 1 (1970), SMS (1974–1975), and TIROS N (1978). The four operational meteorological satellite programs are: TOS/ESSA (1966–1969), ITOS/NOAA 1–5 (1970–1976), GOES (1975 to present), and TIROS N/NOAA 6–7 (1979 and 1981). The meteorological satellites are divided between those that are placed in high geosynchronous orbits (SMS and GOES), and those in lower polar orbits (all the rest). At the end of 1981, the U.S. civilian meteorological satellite system consisted of two geosynchronous satellites (GOES 4 and 5) and two in polar orbits (NOAA 6 and 7).[3]

All launches of U.S. satellites designed principally for meteorological purposes are shown in table 4–1.

TABLE 4–1.—U.S. METEOROLOGICAL SATELLITES, 1960–81

Name	Launch date	Purpose/comments
TIROS 1	Apr. 1, 1960	First global cloud cover picture.
TIROS 2	Nov. 23, 1960	Optical and infrared photos of global cloud cover.
TIROS 3	July 12, 1961	Good cloud cover picture; infrared data.
TIROS 4	Feb. 8, 1962	Supported Friendship 7 flight. Transmitted cloud cover photos till June 1962.
TIROS 5	June 19, 1962	Infrared system inoperative. Good cloud cover pictures.
TIROS 6	Sept. 18, 1962	Infrared sensor omitted.
TIROS 7	June 19, 1963	Transmitted data for nearly 3 years.
TIROS 8	Dec. 21, 1963	Carried automatic picture transmission [APT] system, allowing real-time readout of local cloud pictures using an inexpensive ground station.
Nimbus 1	Aug. 28, 1964	Earth orientation allowed complete global cloud cover pictures every 24 hours. Carried APT for local readout.
TIROS 9	Jan. 22, 1965	First TIROS "cartwheel" configuration for increased coverage of world cloud cover.
TIROS 10	July 2, 1965	First U.S. Weather Service-funded spacecraft. Had two TV cameras similar to TIROS 6.
ESSA 1	Feb. 3, 1966	Initiated the TIROS Operational Satellite system [TOS]. Designated ESSA for the Environmental Science Services Administration (later renamed NOAA for National Oceanic and Atmospheric Administration.)
ESSA 2	Feb. 28, 1966	Permitted local readout of daylight cloud cover by APT TV system. Advanced version of cartwheel design.
Nimbus 2	May 15, 1966	Similar to Nimbus 1. Completed more than 2½ years of operation with three-axis stabilization.
ESSA 3	Oct. 2, 1966	First advanced Vidicon camera system in Tiros/TOS series; also carried infrared Earth heat balance sensor.
ESSA 4	Jan. 26, 1967	Advanced version of cartwheel configuration. Good APT pictures returned.
ESSA 5	Apr. 20, 1967	Carried advanced Vidicon camera system.
ESSA 6	Nov. 10, 1967	Carried two TV systems used for APT ground station.
Nimbus B	May 18, 1968	Launch vehicle destroyed by range safety officer after 2 minutes. Carried 8 experiments, including a radioisotopic thermoelectric generator.
ESSA 7	Aug. 16, 1968	Permitted daily photos of entire globe.
ESSA 8	Dec. 15, 1968	Carried two APT camera systems to obtain daily cloud photos of entire globe.

---

[3] Some data can also be obtained from several of the older satellites if necessary.

TABLE 4-1.—U.S. METEOROLOGICAL SATELLITES, 1960-81—Continued

Name	Launch date	Purpose/comments
ESSA 9	Feb. 26, 1969	Last mission of TOS series.
Nimbus 3	Apr. 14, 1969	Carried experiments identical to those on the unsuccessful Nimbus B.
TIROS M (ITOS 1)	Jan. 23, 1970	Second generation operational meteorological satellite, carrying TV, APT and scanning radiometers for global cloud data for remote and local readout, both day and night.
Nimbus 4	Apr. 8, 1970	Seven of the nine experiments carried were operational.
ITOS A (NOAA 1)	Dec. 11, 1970	Mission designed to provide improved operational infrared and visual observations of Earth cloud cover, both in direct readout and stored modes of operation.
ITOS B	Oct. 21, 1971	Failed due to second stage malfunction. Same mission as ITOS A.
ITOS D (NOAA 2)	Oct. 15, 1972	Same as ITOS A except that a vertical temperature profile radiometer for atmospheric temperature sounding and a very high resolution radiometer for detailed imaging and sea surface and cloud top temperature measurements were carried.
Nimbus 5	Dec. 11, 1972	Stabilized Earth-oriented platform for the testing of advanced systems, sensing and collecting meteorological and geological data.
ITOS E	July 16, 1973	Failed due to second stage malfunction. Same mission as ITOS D.
ITOS F (NOAA 3)	Nov. 6, 1973	Same mission as ITOS D.
SMS 1	May 17, 1964	Part of a global network of geostationary environmental satellites with the objective of providing repetitive Earth imaging of the same area in the visible and infrared spectra.
ITOS G (NOAA 4)	Nov. 15, 1974	Same mission as ITOS D.
SMS 2	Feb. 6, 1975	Supplement for SMS 1.
Nimbus 6	June 12, 1975	Carried nine advanced instruments for remote sensing of the atmosphere.
GOES 1	Oct. 16, 1975	Geostationary operational environmental satellite. Operational version of SMS. Replaced SMS 1.
ITOS H (NOAA 5)	July 29, 1976	Same mission as ITOS D. Last of this series.
GOES 2	June 16, 1977	Second in the series.
GOES 3	June 16, 1978	Third in the series.
TIROS N	Oct. 13, 1978	Third generation polar orbiting experimental spacecraft to provide improved meteorological data. Later made part of operational system.
Nimbus 7	Oct. 24, 1978	Flight tested advanced sensors and technology basic to conducting experiments in pollution monitoring, oceanographic, and meteorological fields.
NOAA 6	June 27, 1979	Operational version of TIROS N.
NOAA B	May 29, 1980	Launch vehicle malfunction placed satellite in wrong orbit; not usable.
GOES 4	Sept. 9, 1980	Fourth in the series.
GOES 5	May 22, 1981	Fifth in the series.
NOAA 7	June 23, 1981	Second operational TIROS N satellite.

Table prepared by Marcia S. Smith, Congressional Research Service. Source: NASA Historical Pocket Statistics (1979) and NASA Pocket Statistics (1980 and 1981).

It should be noted that other satellites have carried experimental meteorological sensors, most notably the Application Technology Satellite [ATS] series used primarily for communication satellite experiments (see chapter 3). These are not included in the table, but are discussed in the text. Also, the meteorological satellite program is inextricably linked with other remote sensing programs such as those for ocean sensing (see chapter 6), earth resources (see chapter 5), and exploration of the upper atmosphere (see volume one, chapter 9).

The Department of Defense operates its own polar-orbiting Defense Meteorological Satellite Program [DMSP], and DOD provides weather data to the civil sector through NOAA, and vice versa.

II. TIROS 1 AND ORGANIZATION OF OPERATIONAL METEOROLOGICAL SATELLITE STRUCTURE

The United States launched its first weather satellite on April 1, 1960. The NASA experimental satellite was named the Television and Infrared Observation Satellite, or TIROS. Pictures from TIROS 1 gave meteorologists, for the first time, an ability to constantly monitor the weather. Developing storms and frontal activity were easily seen in the space imagery,[4] and the photos gave meteorologists their first total view of weather patterns. They revealed a degree of organization never realized from terrestrial and aircraft observations.

The success of Tiros 1 prompted interest in an operational meteorological satellite system. At NASA's initiative, a Panel on Operational Meteorological Satellites [POMS] was established in October 1960 as an interagency working group under the auspices of the National Coordinating Committees for Aviation Meteorology. The agencies participating in the panel were the Departments of Defense (Army, Air Force, and Navy) and Commerce (U.S. Weather Bureau), the Federal Aviation Administration, and NASA.

In April 1961, POMS issued a plan for a national operational meteorological satellite system.[5] The POMS plan recommended that the Weather Bureau[6] assume management responsibility for the national operational meteorological satellite system, or NOMSS. Under contract to the Department of Commerce, NASA would develop and procure the spacecraft and launch vehicles. NASA would continue such ground support activities as tracking and spacecraft control and programing, while the Weather Bureau would be responsible for data processing and dissemination. Upon the approval of the POMS plan by the White House National Aeronautics and Space Council (with the concurrence of the Budget Bureau) a specific request for funds for implementation of the plan was sent to the President. On May 25, 1961, President Kennedy addressed the Congress on "Urgent National Needs."[7] Along with a call to land a man on the moon by decade's end, he requested additional funds for NASA and the Weather Bureau to implement the operational weather satellite system. A total of $50.2 million was appropriated for NASA,[8] and $48 million was appropriated to the Weather Bureau.[9]

Thus, in a period of less than 6 months, the POMS had presented its recommendation for an operational system and had it approved by the President's science adviser, the Space Council, the Budget

---

[4] Space imagery broadly includes all types of images, likenesses, and graphic representations ranging from high resolution photographs and television to the extremely low resolution arrays of dots from banks of photo cells used to estimate cloud cover.

[5] U.S. National Coordinating Committee for Aviation Meteorology. Panel on Operational Meteorological Satellites. Plan for a National Operational Meteorological Satellite System. Washington, D.C. Government Printing Office, 1961, 26 pp.

[6] In 1965 the Weather Bureau was combined with the Coast and Geodetic Survey and the Central Radio Propagation Laboratory of NBS to form the Environmental Science Services Administration [ESSA] in the Department of Commerce. In 1970, when the National Oceanic and Atmospheric Administration [NOAA] was formed within the Commerce Department, weather satellite programs became the responsibility of that agency.

[7] H. Doc. 174, 87th Congress, 1st session.

[8] Public Law 87-141, Aug. 17, 1961.

[9] Public Law 87-332, Sept. 30, 1961.

Bureau, the President, the Congress, and had virtually all of the necessary funds appropriated for fiscal year 1962.

It is interesting to note that during congressional hearings on the national meteorological satellite system, there was some discussion as to whether NASA or the Department of Commerce should manage the system.[10] Those who advocated management within NASA reasoned that the entire civilian space program should be managed within one agency. Those who thought that the system should be managed by the Weather Bureau within the Department of Commerce felt that the user agency should have control over the system. Unlike later debates centering on an operational Landsat system, at no time was NASA's legal authority to manage operational satellite systems questioned, as it has been in recent years.

III. U.S. METEOROLOGICAL SATELLITES

A. Polar-Orbiting Satellites

1. TIROS

The evolution of U.S. weather satellites through changes in technology, orbital configurations, instrumentation and data handling methods began with the TIROS program, which ran from 1960 to 1965.

There were 10 TIROS satellites launched between April 1960 and July 1965, and all 10 were successful. TIROS data were transmitted as late as July 1967. Although the original life expectancy of the spacecraft was to have been from 3 to 4 months, all but TIROS 1 exceeded this; TIROS 8 had the longest useful lifetime, returning data for 3½ years.

TIROS 1-4 were launched typically into 720 kilometer-high orbits inclined at an angle of 48° to the equator, allowing photographic and instrument coverage to about 55° latitude (north and south), but not of the polar regions. For TIROS 5-8 the orbital inclination was changed to 58°, making coverage up to 65° possible.

The last two TIROS's were placed in near-polar orbits. TIROS 10 added another improvement—it was the first TIROS to be placed in a sun-synchronous orbit, meaning that it passed over each longitude at the same local time each day, enabling it to view each place on Earth under uniform lighting conditions. The TIROS orbits then had the spacecraft photographing a different swath of the turning Earth on each orbital pass (each TIROS orbit took about 97-100 minutes). This is the same principle applied in all low-orbit weather satellites.

The satellite itself weighed from 121 to 135 kilograms, depending on the onboard instrumentation, with a cylindrical shape often compared to that of an oversized hatbox. Instruments for the first eight TIROS satellites were mounted in the baseplate, so they looked down through the bottom of the spacecraft at the Earth. The satellite was spin-stabilized, but its spin axis was not aligned with reference to the Earth, so the flat baseplate did not always remain parallel to the Earth's surface.

---

[10] U.S. Congress. House. Committee on Science and Astronautics. National Meteorological Satellite Program. Hearings, 87th Congress, 1st session. July 25, 26, and 27, 1961. Washington, U.S. Government Printing Office, 1961.

As a result, the video cameras pointed at the Earth for only one quarter to one third of each orbit. During the remainder of the time they pointed uselessly at outer space. TIROS 9 inaugurated an improvement with the "cartwheel" configuration, in which the spin axis of the spacecraft was held perpendicular to the plane of the orbit so that in effect the satellite rolled along the orbit like a wheel on its rim. Instead of mounting the cameras so that they pointed down from the base of the satellite, the two cameras were placed on the satellite rim facing outward, 180° apart. Thus, TIROS 9 increased by 3 to 4 times the photographic capability of TIROS 1.

The primary sensors on TIROS were two television (vidicon) cameras, one wide-angle and the other narrow-angle, and low and medium resolution infrared radiometers. The TV cameras provided cloud pictures. The infrared radiometers returned data that could be used to determine the temperatures of clouds, their height, and moisture content.[11]

Operation of TIROS consisted basically of commanding the satellite to photograph and to transmit pictures and other data to the ground. The satellite control center computed the command signals to be sent to the satellite and passed this information to the command and data acquisition stations [CDA]. The CDA stations transmitted the commands to TIROS as it passed overhead. When the satellite reached the sunlit portion of the orbit, a clock system in the satellite started the camera. Every 30 seconds after start time the camera took a picture, until 32 pictures were recorded on the satellite's magnetic tape. A limit of 32 pictures per camera was imposed by the capacity of the magnetic tape storage. As the satellite returned to within telemetry range, the CDA station commanded the satellite to transmit stored pictures and other data, to transmit direct pictures if the station was in daylight, and finally to set the clock for the next orbit.

An important development in NASA's experimental program was automatic picture transmission [APT] first carried on TIROS 8, in 1963. For some nations the cost of building facilities for receiving data from the United States was prohibitive. In addition, many nations lacked the technical capability to process and analyze the data. APT systems make spacecraft images available at a minimum cost to any user within radio range of the satellite. A video picture is shuttered, then scanned slowly for immediate transmission to Earth rather than later "dumping" at a large CDA station. The transmission is made on a relatively narrow bandwidth so that the signal can be received and displayed by low-cost ($20,000–$25,000) receiving sets. The APT channel of a satellite operates continuously, thus allowing any nation, group, or even private citizen to secure an instantaneous picture of its atmosphere as a satellite equipped with APT passes overhead. APT data are now received by 871 known stations in 123 countries throughout the world.

One of the goals of the TIROS experimental program was to integrate satellite imagery into the process of weather forecasting. With imagery provided by NASA, meteorologists learned to use the new satellite data in the preparation of their forecast charts, and

---

[11] Infrared sensors were not included on TIROS 6 in order to speed up its preparation for launch after one of the cameras on TIROS 5 failed July 6, 1962.

TIROS began to be used operationally in a limited way. The types of information which could be gleaned from the photos increased in number as photointerpretation techniques improved. As an example, TIROS 2 showed that weather satellites might be used to indicate ice boundaries on water, when it photographed the breakup of pack ice on the St. Lawrence River.

After the launch of TIROS 6 on September 18, 1962, there were at least two TIROS satellites operational at any one time through the end of the program.

2. Nimbus

The next generation of NASA experimental weather satellites was the Nimbus series, with seven successful launches from 1964 to 1978.[12]

The Nimbus program was initiated by NASA early in 1960, its goal to develop an observatory system capable of meeting the research and development needs of the Nation's atmospheric and Earth scientists. Nimbus had been expected to succeed TIROS in the operational weather satellite system, but cost increases and technical problems led to the decision to use Nimbus only for research purposes and to develop a new operational satellite based on proven TIROS technology. Consequently, Nimbus became the Nation's principal satellite program for remote sensing research in low orbits.

Nimbus 1 was launched on August 28, 1964. This more sophisticated satellite was approximately three times the size and weight of TIROS, and its modular design allowed a variety of experiments to be added to the basic power, communications and stabilization subsystems on successive flights. Nimbus 1 carried three instruments, and each "observatory" grew significantly in sophistication, weight and performance.

Unlike TIROS, Nimbus kept its instruments pointing continually down at the Earth with its three-axis Earth-oriented stabilization system. Nimbus satellites were placed in sun-synchronous near-polar orbits which provided global coverage twice in each 24-hour period.

The seven Nimbus spacecraft have been used for development, testing and application of a number of new and advanced meteorological and geophysical remote sensing instruments, cameras and associated data-transmission and processing techniques. Nimbus satellites flight tested the Automatic Picture Transmission [APT] system used on the ESSA series[13] and the high-resolution infrared scanning radiometer [HRIR]. They tested the forerunner to the vertical temperature profile radiometers used on the ITOS series (providing the first satellite soundings of the atmosphere), as well as data collection and relay devices to be used on future satellites.

Another Nimbus achievement (on Nimbus 1) was the successful testing of the Advanced Vidicon Camera Subsystem [AVCS], which greatly improved the quality and resolution of satellite cloud photos. The AVCS was then used in coordination with APT cameras in the ESSA series. Nimbus 6 was used in yet another capacity—the tracking of explorers. In 1978 a Japanese explorer traveling alone to the North Pole carried a transmitter on his dog sled which sent a signal to Nimbus 6 once a minute so that his position could be tracked. Similarly, a desert expedition through the Western Desert of Egypt was tracked using Nimbus 6 later in 1978.

---

[12] Nimbus B, launched May 18, 1968, never achieved orbit.

[13] TIROS 8 was actually the first satellite to fly APT cameras, but the spacecraft's spin prevented a full test of the system as it was operationally designed.

Nimbus 7, the last in the series, was launched on October 24, 1978. The satellite was the first designed to measure various atmospheric gases and pollutants in the stratosphere and mesosphere. Nimbus 7 carried a total of eight sensors, several of which were improved versions of instruments flown on previous Nimbus spacecraft. The instruments supported three disciplines: pollution monitoring, meteorology, and oceanography.

One device, the Coastal Zone Color Scanner [CZCS] was particularly important to oceanographers, in that it allowed analysis of ocean content over larger areas than was possible from ship observations. In addition to mapping chlorophyll, sediment and salinity distribution in coastal regions or open ocean waters (as determined by their characteristic absorption and scattering of light), the CZCS was also used to map temperatures of the waters near the coast or farther out at sea. The detection of chlorophyll concentration indicates the presence of phytoplankton, and so can be used to assess the likelihood of finding fish in a certain part of the ocean.

The CZCS project evolved from a series of measurements made between 1969 and 1973 to determine if ocean color could be sensed through the Earth's atmosphere, and if sufficient information of interest to oceanographers could then be extracted from that color.[14] The instrument placed on board Nimbus 7 is a multispectral line scanner, sensitive in six channels—five bands of the visible spectrum and one in the infrared. Infrared measurements provide information on the temperature of coastal waters as well as the open ocean. All six channels operate by day, whereas only the infrared (10.5-12.5 micrometer) instrument can return date at night.

Since it was anticipated that surface sun glint would pose a serious threat to ocean color observations, a feature was included in the CZCS that allows the angle of a scan line to be tilted either ahead of or behind the spacecraft.

At the beginning of the Nimbus 7 operation, two hours per day were allocated to CZCS operation, but this was later reduced. Scheduling of CZCS imagery is carried out on a priority basis, and ship operations where simultaneous measurements can be conducted with space imagery are given highest priority. There are also certain areas of high priority coverage, such as United States and European coastal waters.

The CZCS instrument was still returning data from space at the end of 1981, and methods of using the data were undergoing evaluation by the community of oceanographers. At a joint COSPAR/SCOR/IUCRM symposium held in 1980 to discuss space oceanography,[15] a number of papers were presented dealing specifically with CZCS. In an introductory paper, H. R. Gordon and Y. R. Morel referred to the "high quality of the CZCS imagery" and stated:

---

[14] Hovis, Warren. The Nimbus Coastal Zone Color Scanner [CZCS] Program. In Gower, J. F. R., ed. Oceanography From Space. New York. Plenum Press. 1981. p. 212.

[15] COSPAR is the Committee for Space Research, and SCOR is the Scientific Committee for Oceanic Research, both of the International Council of Scientific Unions [ICSU]. IUCRM is the Inter-Union Commission on Radio Meterorology. The symposium papers are reprinted in the previously cited "Oceanography from Space," edited by Gower.

> It is now clear that there is considerable horizontal structure in the color of the ocean, and that the CZCS is without doubt capable of delineating this structure even in the presence of very turbid atmosphere.

In the same paper the authors referred to the successful utilization of CZCS data in biological research by the National Marine Fisheries Service, the Scripps Institution of Oceanography and the Southeast Fisheries Center. CZCS data had influenced the choice of cruising areas for research vessels.

Another application of CZCS data has been in the West Coast Fisheries Demonstration Project, conducted in 1981, where CZCS images sent by facsimile to ships at sea have correlated very well with conditions observed on the ocean. Although reflective pollutants such as acid waste and sewage sludge show up clearly in CZCS imagery, and more use of this capability is possible with tracer dyes, little research has been done on the CZCS's ability to monitor water pollution.[16]

An improved CZCS, with more spectral bands and a greater amount of data returned during each day of operation, was to have flown on the National Oceanic Satellite System [NOSS] before that program was canceled (see chapter 6). NOAA is conducting a study of placing an improved operational CZCS on the NOAA H weather satellite. In addition, an ocean color experiment was flown on the second test flight of the Space Shuttle in 1981.

Nimbus spacecraft, the forerunners of the highly successful Landsat earth resources satellites (see chapter 5), have returned a wealth of new data applicable to meteorology, oceanography, geology and hydrology, and continue to transmit these data at the end of 1981.

3. TOS/ESSA

The first operational meteorological satellite system was inaugurated in February, 1966, with the launch of ESSA 1. Administratively, the new system was managed by the National Environmental Satellite Center [NESC] of the Environmental Science Services Administration [ESSA] in the Department of Commerce.[17] In operating the National Operational Meteorological Satellite System, NESC was responsible for: command and control of the satellites in orbit; data acquisition, processing, dissemination and archival; maintenance and improvement of ground data handling systems; future spacecraft system plans; coordination with NASA for the development of new and improved sensor systems; and the procurement of spacecraft, launch vehicles and launch services. It was also a function of NESC to conduct research and development on the analysis and application of satellite date. Satellite technology research and development, and the launching of spacecraft were to remain NASA's responsibilities.

---

[16] Dr. Warren Hovis, of NOAA's National Environmental Satellite Service [NESS]. Telephone communication, Apr. 5, 1982. Dr. Hovis headed the CZCS experiment team.

[17] Later renamed the National Environmental Satellite Service [NESS] when NOAA was formed in 1970.

Technically, the new system employed the TIROS Operational Satellite [TOS] spacecraft (renamed ESSA, for Environmental Survey Satellite, upon reaching orbit successfully) which were based on the proven technology of the TIROS experimental satellites. ESSA 1 was identical to the TIROS 9 spacecraft used to test the TOS system concept. Later ESSA satellites were considerably modified and improved.

The TOS system consisted of two types of ESSA spacecraft in orbit simultaneously. One type (those assigned odd numbers) was equipped with an Advanced Vidicon Camera System [AVCS], which provided global coverage by storing pictures for later transmission to CDA stations in Alaska or Wallops Island, Virginia. From there the pictures and data were relayed to Washington, D.C. for processing and analysis. The second type (even numbers) was equipped with direct transmission APT cameras. It photographed and immediately sent the pictures to APT ground stations within range of the satellite.

Operation of the ESSA series was much the same as that of the TIROS series. The near-polar sun-synchronous orbits of the ESSA spacecraft permitted complete Earth coverage. A command to photograph was sent to the satellite so that pictures were taken over the sunlit side of the Earth. The greater altitude at which later ESSA satellites operated made possible complete photographic coverage with only six pictures per orbital pass over the sunlit side of the orbit. Twelve pictures, with 50 percent overlap from picture to picture, were normally acquired on each pass. Thus, the satellite provided global coverage by means of 144 to 156 pictures every 24 hours. TIROS 9 and ESSA 1 required between 450 and 500 pictures for the same overlapping coverage.

4. *ITOS/NOAA 1-5*

With the launch of the first improved TIROS Operational Satellite [ITOS] in 1970, the second generation of polar-orbiting satellites came into being. It dramatically exceeded the capabilities of the first generation TOS/ESSA series. ITOS coincided with the formation of the National Oceanic and Atmospheric Administration [NOAA] which assumed the duties of the now defunct ESSA.

ITOS 1,[18] NASA's experimental prototype for this satellite, was launched on January 23, 1970 and became operational in June 1970. NOAA 1,[19] the first NOAA operational spacecraft of the ITOS series, was launched December 11, 1970 and contained the same instrument package as ITOS 1.

The ITOS spacecraft was designed to perform the work of a pair of ESSA spacecraft. It had APT as well as AVCS capability, permitting the satellites to transmit both real-time photographs and stored images. Night-time coverage was provided by the addition of a scanning radiometer [SR]. SR data were stored on magnetic tape for later readout at the CDA stations and also were broadcast through the APT transmitter for local ground reception. These capabilities permitted operational day and night coverage for the first time.

---

[18] Previously designated TIROS M.

[19] Previously designated ITOS A.

In addition, the ITOS/NOAA satellites carried a Solar Proton Monitor, the first nonmeteorological instrument to be carried on operational satellites. Measurement of the solar proton flux is useful for estimating the degree of activity of the Sun. Such information can be used in forecasts of radio communications conditions. They also carried a flat plate radiometer [FPR] which furnished atmospheric heat balance measurements.

NOAA 2, launched October 15, 1972, was redesigned to incorporate two new instruments and to eliminate the APT and AVCS cameras as well as the flat plate radiometer. With the addition of the very high resolution radiometer [VHRR] and the vertical temperature profile radiometer [VTPR], NOAA 2 became the first weather satellite to have no cameras and to rely entirely on radiometers for visual and infrared images, as well as the first to carry an operational instrument capable of obtaining vertical temperature profiles of the atmosphere over most of the Earth.

The VHRR sensor measures cloud top temperatures or ground and sea surface temperatures in clear areas, both by day and by night, and transmits these data in real time to high resolution picture transmission receiving stations [HRPT].[20] In addition, 8 minutes of data per orbit may be stored in the satellites for later playback to the CDA stations. The operation of the two-channel VHRR is similar to that of the scanning radiometer, but the data are of much higher resolution. One channel measures reflected visual radiation and the other measures infrared radiation. The VHRR data provide more contrast between the Earth and clouds than do the SR data.

NOAA 3, 4, and 5 were identical to NOAA 2. NOAA 5 was deactivated on July 16, 1979, signalling the end of the ITOS/NOAA series.

5. TIROS N/NOAA 6-7

The launch of the TIROS N satellite on October 13, 1978, inaugurated the third and present generation of polar orbiting environmental satellites.[21] TIROS N carried several improved instruments. One was the advanced very high resolution radiometer [AVHRR] that had four spectral channels (instead of two) to provide day and night sea surface temperatures, ice, snow, and cloud over information. TIROS N also carried the TIROS operational vertical sounder [TOVS] package to provide improved temperature and moisture vapor content measurements of the atmosphere. One of the three TOVS instruments operated in the microwave region which can penetrate cloud layers, so data can be returned regardless of the amount of cloud cover. The spacecraft also had an upgraded Space Environmental Monitor to give more accurate alerts of high energy solar radiation levels, which is important to manned spacecraft missions, high altitude commercial aircraft flights, long range communications, and electric power distribution networks.

---

[20] Only 47 stations worldwide are equipped to receive the digital HRPT data, whereas some 871 can receive the lower resolution APT transmissions.

[21] The TIROS N spacecraft is based on the Block 5D bus developed for the Air Force and used in the defense meteorological satellite program.

TIROS N also carried a data collection and location system provided by France, known as Argos, that represented an improvement over the data and collection systems on geostationary satellites. It was capable of receiving data from fixed or moving platforms on land, sea, and air, and determining the precise geographic location of each one. This was used to calculate the velocity of the fluid on which the platform "rode."

The TIROS N spacecraft was technically a NASA experimental satellite, but it was used operationally. Operational versions of this series continue the NOAA numbering system, and the first of these was NOAA 6, launched June 27, 1979. It was identical to TIROS N. NOAA 7, launched on June 23, 1981, was essentially the same spacecraft with the exception of another channel added to the AVHRR[22] to improve measurements of sea surface.

The TIROS N series of spacecraft are the first all-digital polar orbiters. The information flow from each TIROS N satellite is 1.33 million bits per second, increasing by more than 100 percent the burden upon the communications and data processing system as compared to the previous generation of polar-orbiters. To meet this demand, the system needed technological improvements: an automated command and control system, new computers at the CDA stations, minicomputers on board the satellites for some data processing prior to transmission; and, data transmission via a commercial communications satellite from the CDA's to National Environmental Satellite Service [NESS] in Suitland, Md. The flow rate is so large that it must be slowed before processing, so a bank of 14 staging computer disks temporarily holds the data for feeding into a trillion-bit memory archiving system. From there, the information is moved to other computers for the generation of quantitative products which are distributed to users worldwide.

B. GEOSTATIONARY SATELLITES

The geostationary satellite represents a great advance in meteorological satellite capability. Although it is incapable of viewing polar regions, the advantage of its 35,800 kilometer-high geosynchronous orbit is that it is relatively immobile in relation to the Earth's surface and can therefore provide continuous coverage of the same portion of the globe. Continuous coverage is particularly significant for the detection and tracking of severe storms which are small in size and transient in nature. These satellites enable meteorologists to study tornadoes which strike quickly and with little warning. They also permit constant monitoring of larger weather patterns such as tropical storms. In addition, it is possible to measure the velocity of winds by tracing selected clouds imaged at short intervals and deriving the direction and speed of their movement.

1. ATS

Preliminary meteorological experiments were first performed aboard the NASA experimental synchronous satellites known as the Applications Technology Satellite [ATS] (see Chapter Three).

---

[22] Actually, one channel was split in two temperatures.

ATS 1, launched December 6, 1966, was placed into geostationary orbit over the Pacific Ocean at the Equator. Four days later the satellite began continuous photographic coverage of the Pacific basin and Western United States with a spin scan cloud camera which returned the first black-and-white full-disc picture of the Earth. ATS 3 was also a major success. It carried a color spin scan cloud camera and viewed much of North America, the north and south Atlantic Ocean, all of South America and the western edges of Africa and Europe. These cameras proved the usefulness of weather satellite imagery from the high synchronous orbit.

Several important weather communications techniques were tested on the ATS system, one of which was the WEFAX experiment. In the WEFAX system the satellite serves as a relay station for broadcast of weather information of interest to the portion of the globe covered by the satellite. Information is in the form of satellite pictures and weather maps, and the broadcasts can be received by anybody who has the required receiving set.[23] WEFAX serves ships at sea as well as land stations, and for those nations within view of a WEFAX-equipped satellite it offers an important supplement to the APT service furnished by the NOAA satellites. At the end of 1981 there were 145 stations receiving WEFAX broadcasts worldwide from geostationary GOES satellites (see below).

Although the ATS satellites were able to view the Earth only in daylight, their successes formed the technological base from which the SMS/GOES program began.

2. SMS/GOES

On May 17, 1974 the first NASA Synchronous Meteorological Satellite [SMS] was launched. Initially it was used to support the Global Atmospheric Research Program [GARP] (see below). SMS 2 was launched on February 6, 1975. Geostationary Operational Environmental Satellite [GOES 1], the first NOAA-funded operational spacecraft of this series, was launched on October 16, 1975. It was followed by GOES 2, 3, 4, and 5 in 1977, 1978, 1980, and 1981, respectively. With these satellites the useful camera coverage and communications range extends westward from Western Europe and Africa to the western Pacific Ocean and includes all of North and South America.

The principal instrument of the SMS series and the first three GOES satellites was an improved radiometer, the Visible and Infrared Spin-Scan Radiometer [VISSR]. It took visual images of the Earth's surface and cloud cover, and took infrared sea surface temperature data. The radiometer could scan the full portion of the Earth within its view in approximately twenty minutes. If meteorologists wished to monitor a severe storm, the satellite could limit its scan and provide a picture of the storm area every 15 or even every 5 minutes. Thus, in the limited scan, coverage of territory is traded for frequency of scan in a lesser area.

GOES 4, launched on September 9, 1980, carried an improved version of the VISSR which provided not only imagery, but also atmospheric temperature and water vapor soundings as a function of altitude in the atmosphere. Called the VAS (for VISSR Atmospheric Sounder), it has twelve infrared sensing bands compared to one such channel on the VISSR. At its current state of development, the VAS cannot obtain sounding data and imagery at the same time, however. GOES 5, launched on May 22, 1981, also carried a VAS, and replaced an older-model SMS/GOES over the eastern half of the United States.[24]

---

[23] WEFAX receivers cost from $12,000 to $15,000 in 1981.

Data from the VAS are important in forecasting and monitoring the strength and course of highly localized severe storms, such as thunderstorms, hurricanes and severe winter snow storms. The inclusion of VAS—an experimental instrument—onboard an operational spacecraft was part of NASA's operational satellite improvement program designed to save funds by combining research and operational sensors when possible.

The SMS/GOES satellites also carry a package of Space Environmental Monitor [SEM] instruments, as do the NOAA satellites. The SEM instruments include a magnetometer, a solar X-ray telescope, an energetic particle monitor, and, on GOES 4 and 5, a High Energy Proton and Alpha Detector [HEPAD]. These instruments take measurements of solar activity and provide data on the Sun's interaction with terrestrial fields.

Another important payload of the SMS/GOES satellites is the Data Collection System [DCS] which collects and relays environmental data sensed by more than 1,500 widely dispersed platforms such as river and rain gages, seismometers, tide gages, buoys, ships, and automatic weather stations. Each platform must be equipped with a data collection platform radio set to provide the communication link between the platform and the satellite. Platforms then transmit sensor data by radio, either at scheduled intervals or upon interrogation from the satellite. Platforms may also operate in an emergency alarm mode, during which a signal is transmitted immediately whenever an observational parameter exceeds a preset threshold value. Data received by the satellite are transmitted to the Wallops Island CDA Station and relayed to the World Weather Building in Camp Springs, Maryland. From there the data are disseminated by paper tape fed into a telephone system using commercial circuits. The GOES DCS began service on August 18, 1975. The SMS/GOES satellites also carry the WEFAX capability.

C. EXISTING OPERATIONAL METEOROLOGICAL SATELLITE SYSTEM

The current operational meteorological satellite system is comprised of both polar-orbiting and geostationary satellites. The polar-orbiting satellites obtain quantitative global environmental data used to derive profiles of atmospheric temperature and moisture, sea surface temperature observations, and snow and ice coverage, and they relay environmental data from fixed and moving remote platforms. All these data and products are used in numerical weather analysis and prediction, oceanographic, hydrologic, agricultural and solar radiation studies. Data from the polar orbiters are received by 871 APT stations around the world as the satellite passes overhead.

---

[24] Several of the geosynchronous satellites launched to date have been transferred to different "hovering" spots during their operational lifetimes.

The geostationary satellites provide the repetitive 24-hour images that are needed to detect, track and monitor the growth and decay of severe weather systems in the temperate and tropical latitudes. They also continuously collect environmental data from fixed platforms and are used to retransmit satellite-derived products to national and international users via Weather Facsimile [WEFAX].

At the end of 1981 two polar orbiters (NOAA 6 and NOAA 7) and two geosynchronous satellites (GOES 4 and GOES 5) were operational. The two NOAA satellites are in orbits spaced apart in such a way that they provide maximum daylight coverage of the whole globe. GOES 4 is situated at 135° west longitude, and covers the Western part of the United States and the Pacific. GOES 5 is over the equator at 85° west longitude, and so looks down on the eastern and Atlantic side of the continent.

IV. FUTURE METEOROLOGICAL SATELLITES

In the immediate future, the United States weather satellite program will continue with the successful dual system of GOES geostationary and NOAA/TIROS N polar orbit satellites. GOES F, planned for launch in 1983, will be the same spacecraft as GOES 4 and GOES 5. The earliest instrument changes anticipated in the GOES series are for GOES G, tentatively scheduled for launch in 1984.

At the end of 1981 it was not certain what those changes might be. Planners in the National Environmental Satellite Service [NESS] have proposed that contract bidders for the building of later GOES satellites research and develop new instrument changes that would increase the satellite's performance as meteorological sensor. In addition, planners in NASA's Office of Space Science and Applications are assessing the VAS infrared sounder and its future scientific capabilities as an operational instrument.

Whatever the changes in instrumentation, an established goal is to keep two of these geostationary satellites over American longitudes at any one time. Launch plans for future GOES satellites will likely be geared to the working health of spacecraft already in orbit.

Polar orbiters will continue with the existing TIROS N model spacecraft, with only slight modifications to accommodate new instrument payloads. NOAA E, scheduled for February, 1983, will carry the international Search and Rescue [SARSAT] payload (discussed in Chapter Three). NOAA D, scheduled for launch in August, 1984, will not.[25] NOAA F and succeeding NOAA satellites are scheduled for launch at 18-month intervals after the launch of NOAA D. By the end of 1981, NOAA had contracted to build through spacecraft "J" in the series. Beginning with NOAA F the satellites will carry two experiments new to the TIROS N series—the Earth Radiation Budget Experiment [ERBE] and the Solar

---

[25] The reversed lettering order here is a result of advancing the NOAA E launch date to get the SARSAT system aloft as early as possible.

Backscatter Ultraviolet [SBUV] radiometer. Both of these are based on technologies used in the Nimbus satellite series.

The ERBE instrument is designed to provide data on the Earth's balance of incoming and outgoing radiant energy. The SBUV experiment detects ozone concentrations in the atmosphere as part of NOAA's program to monitor pollutants and minor constituents of the atmosphere.

For later TIROS N/NOAA missions, NASA's Office of Space Science and Applications is researching further advances in the capabilities of the TOVS instruments, including the addition of more spectral channels to the Microwave Sounding Unit and the improvement of sea surface temperature measurements by the infrared temperature sounder.

At the end of 1981 there were no plans for major generic changes in U.S. weather satellites. NASA does have an ongoing research interest in the LIDAR, or "light radar" concept, however. One version would use laser beams to measure such variables as cloud heights and atmospheric densities. Especially valuable would be the measurement of atmospheric wind speeds, a capability lacking in current satellites and one that would mean much to meteorologists. Because laser light beams are monochromatic (of a single wavelength) they could be used for Doppler tracking of winds.

NASA has conducted Doppler LIDAR tests on its Convair 990 aircraft in 1981, and more tests are planned for 1983. Among the questions still to be resolved are how to increase the lifetime of the laser systems and which wavelengths would be the best for meteorological studies. At present too cumbersome and expensive, it is not expected that a LIDAR weather satellite could fly before the early 1990's.

V. PARTICIPATION OF THE UNITED STATES IN INTERNATIONAL METEOROLOGICAL PROGRAMS

The United States participates in international meteorological programs through the World Meteorological Organization [WMO]. The WMO is a specialized agency of the United Nations created in 1951 to establish, coordinate and improve meteorological services throughout the world. Membership in the WMO is open to any state, territory or group of territories which maintain a meteorological service. WMO membership numbered 147 in 1981. U.S. meteorological satellites, both polar-orbiting and geostationary, contribute to this effort. WMO members obtain access to meteorological information from satellites indirectly through a WMO network of international, regional and national meteorological centers, and directly from the Automatic Picture Transmission broadcasts.

A. Equipment and Training

Since the launch of the first APT-equipped satellite in 1963, 871 APT receivers have been placed in operation by government agencies in 12 countries (including the U.S.S.R. and the People's Republic of China) as well as academic institutions, scientific groups, local communities, commercial television stations, Boy Scout troops, and private individuals throughout the world. Although the official cost estimate for an APT terminal is approximately $20,000 to $25,000, home-manufactured receivers have been constructed for considerably less.

The United States has not only developed equipment which can be used internationally, it also provides training in the use of the equipment as well as assistance in processing and interpreting data derived from the equipment. Such aid proved particularly important when the United States switched from video cameras to scanning radiometers on its weather satellites in the early 1970's, since the new images required some adjustment after they were received. The United States has contributed equipment and services through the voluntary assistance plan of the WMO.

B. World Weather Program

The World Weather Program consists of the World Weather Watch [WWW] and the Global Atmospheric Research Program [GARP]. The WWW and GARP are the focal points in the WMO for the use of space technology. Meteorology has a dual character as a branch of the physical sciences and as a public service, leading to its peculiar position as part of both basic research and operational systems. As a result, there is a mutual exchange between scientists who use empirical data from operational meteorological systems to better understand weather phenomena and weathermen who use the knowledge gained from experiments to improve their prediction ability. Because of this mutual relation, both the operational WWW and scientific GARP aspects of the program are discussed in this section.

1. World Weather Watch [WWW]

In December 1961 the United Nations General Assembly, recognizing the potential of space technology, adopted resolution 1721(XVI) relating to international cooperation in the peaceful uses of outer space. One section of the resolution called upon the WMO to examine the potential value of space techniques in meteorology. The study concluded that there was a need to support a single global meteorological service—the World Weather Watch [WWW].

The operational elements of the World Weather Watch are the Global Observing System [GOS], Global Data Processing System [GDPS], and the Global Telecommunications System [GTS].

a. Global Observing System [GOS].—GOS provides meteorological and related environmental data from both satellite and ground-based observations. Space data are derived from both polar orbiters and geostationary satellites. Satellites from the United States, Japan, and the European Space Agency [ESA] all contribute. The Soviet Union has promised to provide a satellite as part of this program, but apparently encountered technical difficulties. By December 1981 the Soviets had never launched a geostationary weather satellite.

The present geostationary system includes the two United States GOES satellites at 85°W and 135°W longitude, ESA's Meteosat at 0° longitude, and Japan's Himawari, stationed at 140°E longitude. The Global Observing System also includes the subsystem of surface and upper-air stations—aircraft, data collection platforms, buoys, ground weather radar stations, instrumented ships, et cetera.

b. Global Data Processing System [GDPS].—This system is designed to make available to the meteorological services of the world processed data and products required for preparing forecasts and warnings and for climatological and research purposes on both a real-time and delayed basis. The GDPS operates on three levels: international, regional and national. The World Meteorological Centers [WMCs] are located in Washington, D.C., Moscow, and Melbourne, Australia (limited capability). They process data from the GOS and transmit meteorological analyses on a global scale to WMO member nations through the GTS. The Regional Meteorological Centers [RMC] furnish processed data and forecasts on a regional basis. For example, the area of the Caribbean, Central America, and northern South America is served by an RMC at Miami. Finally, located in nearly all member WMO nations are the National Meteorological Centers [NMC]. They are intended to satisfy data processing needs on the national level, assisted as required by the products of the WMC and RMC network. The integrated GDPS utilizes high-speed computers and data-handling equipment which makes routing and processing large amounts of global data possible with a minimum duplication of effort.

c. Global Telecommunications System [GTS].—The GTS is comprised of the telecommunications facilities for rapid collection and exchange of basic observational and processed data. Like the global data processing system it also operates on three levels: the main trunk circuit (global), the regional telecommunications networks (regional), and the national telecommunications networks (local). GTS issues thousands of bulletins daily. Satellites play an important role in the GTS, and when used in combination with other techniques they vastly improve the overall efficiency of the WWW in obtaining and using data. Collection of data from ocean-based platforms is a good example.

2. Global Atmospheric Research Program [GARP]

In 1962 the United Nations passed resolution 1802(XVII) inviting the International Council of Scientific Unions [ICSU] through its member unions and national academies to develop an expanded program of atmospheric science research that would complement the programs fostered by the WMO. The result was the 1967 agreement between WMO and ICSU on the Global Atmospheric Research Program [GARP]. The program includes theoretical, numerical and observational experiments designed to improve understanding of the Earth's atmosphere and to develop and test physical-mathematical models.

Global observations are of particular value to the GARP program for several reasons. The particular value of satellites is their global coverage, which is required for two reasons. First, it is needed as a starting point for global weather forecasts that use existing physical-mathematical models of the total Earth atmosphere. The quality of these forecasts reflects directly the completeness of the observations used to describe the present atmospheric state, from which the models then forecast future states. Second, global observations are needed to test, verify, and improve the performance of existing models. Only by comparison with actual observations, many of which are made possible only by satellites, can critical improvements be achieved. For these reasons, satellite data have been an important component of the numerous GARP experiments.

GARP has conducted many regional experiments in pursuit of its goals of trying to improve the science of weather forecasting and to understand the physical bases of climate and its fluctuation. Among these regional experiments have been the GARP Atlantic Tropical Experiment [GATE] conducted in the summer of 1974 with one of its goals to assess the effects of small-.scale tropical weather systems on the larger scale atmospheric circulation; and the Polar Experiment [Polex] designed to examine the role of polar regions in global energetics.

The Global Weather Experiment, also known as the First GARP Global Experiment [FGGE], deserves special attention here. Conducted from December 1978 to November 1979, it was one of the most extensive international science experiments in history, involving over 140 countries. The experiment's goal was to try to find the practical limits of weather forecasting and to design an appropriate worldwide coordinated observation system.

United States participants included the Departments of Commerce, Defense, Energy, Interior, Transportation and State; NASA; the National Center for Atmospheric Research [NCAR]; the National Science Foundation; the Defense Nuclear Agency; and many academic institutions.

Ten space satellites were involved in the project, including six from the United States [26] and two polar orbiters from the U.S.S.R.

The scope of the Global Weather Experiment was vast. For a brief period, routine weather observations around the planet were greatly stepped up. Some 50 ships from 22 nations released radiosonde weather balloons daily. Three hundred instrumented buoys were deployed over sparsely reported ocean areas in the Southern Hemisphere, all monitoring sea and atmospheric conditions for relay to satellite. Commercial and government airplanes returned wind, temperature and pressure data.

At the conclusion of the observing year in November 1979, GARP researchers had collected millions of bits of data from these and other sources. The initial information processing was subdivided among 22 data centers throughout the world. Data were refined for transmission to World Data Centers in the United States and U.S.S.R., and to meteorological research laboratories in Bracknell, England and Princeton, N.J. These data are still being refined and applied toward gaining an understanding of eleven months of world weather history, and by extension, an understanding of how the atmosphere behaves.

VI. VALUE OF METEOROLOGICAL SATELLITES [27]

Since TIROS 1 provided the first regular views of the Earth's atmosphere from space in 1960, weather satellites have had a lasting impact not only on the growth of the science of meteorology, but also on the public and private uses of weather data. Satellites show the organization of storms and other atmospheric phenomena with a clarity never approached by aircraft, radiosonde balloons, or any other technology previously available.

---

[26] TIROS N, Nimbus 7 and NOAA 6 were the polar orbiters. For the experiment, the United States also moved a GOES stationary satellite to fill a gap over the Indian Ocean, in addition to the two maintained over American longitudes.

[27] See vol. 1, chapter 14 for further information.

Perhaps the most significant contribution of satellites to the science of meteorology has been their continuous supply of global weather data. Before TIROS, there were large gaps in the record of Earth's daily weather, due to the limited number of observation posts in remote regions of the oceans and uninhabited areas such as deserts. Now we receive daily data from satellites about temperatures and cloud cover over every spot on the globe. Weather forecasts for the west coast of the United States have particularly improved in the satellite era, since most of that region's weather originates in the Pacific Ocean, once a very sparsely reported area. As a result of satellite coverage, NOAA was able to save money by the retiring of weather station ships in 1975.

This closing of the data gap has been invaluable to meteorologists in their attempt to understand the Earth's constantly mixing atmosphere as a total, global system. The flow of satellite data, when augmented by increasingly better computers and data processing techniques, has helped scientists in their formulation of mathematical models of the atmosphere's behavior, the final goal of which is a workable, accurate Numerical Weather Prediction system. The realization of that goal is still in the future, and will probably involve not only readings from weather satellites—temperature and humidity soundings, cloud data, et cetera—but input from conventional weather stations and other types of environmental satellites including the upper atmosphere Explorers and oceanographic sensors. (As an example, ocean wind-velocity measurements from the Seasat scatterometer instrument have been plugged in for experimental use in numerical weather prediction models.)

Already, though, the impact on forecast accuracy has been great. The National Meteorological Center's pressure and precipitation forecasts reportedly improved by 28 percent (at sea-level) from 1958 to 1972, while skill in forecasting precipitation increased by approximately 13 percent from 1960 to 1971.[28] George S. Benton, a former president of the American Meteorological Society, testified before a House subcommittee that "today, operational weather forecasts made 48 hours in advance are as accurate as forecasts made 24 hours in advance two decades ago (before the advent of weather satellites)."[29]

As a result of coordinated satellite-dependent research efforts like the Global Weather Experiment and other GARP programs, meteorologists hope to find the means to further extend the range, scope and accuracy of their forecasts.

The users of these forecasts, and of satellite data in general, are widely scattered and many. They include the National Weather

---

[28] Brown, H. and Fawcett, E. "Use of Numerical Guidance at the National Service's National Meteorological Center." Journal of Applied Metorology, 554 (11). November 1972. pp. 1175–77.

[29] Benton, George S. Testimony before House Science and Technology Committee, Subcommittee on Natural Resources, Agriculture Research and Environment. Feb. 23, 1982. Unpublished.

Service, Government agencies, the Department of Defense, university and research concerns, foreign meteorological agencies, aviation weather services, private industries, news media, and private citizens equipped with the necessary receiving stations. The National Environmental Satellite Service [NESS] disseminates weather satellite pictures, data and bulletins daily to thousands of users. Archived information and real-time products as well as direct readout transmissions by APT or WEFAX are available. Each day the national daily weather picture from the stationary GOES satellites is widely distributed to commercial wire services for TV news and newspapers, as is the Satellite Weather Summary prepared by NESS. There is scarcely a television weather forecaster in the country today who does not use satellite photography and satellite-data-based summaries in preparing the daily local forecasts used by millions of viewers in planning daily activities.

One of the great contributions of weather satellites has been the identification and tracking of hurricanes, tornadoes, tropical storms, severe local thunderstorms, winter storms and other destructive weather phenomena. The study of hurricanes has been especially enhanced by satellite data. From the earliest TIROS pictures scientists have been able to watch the birth of spiralling storms over the ocean, monitor wind circulations to see if the hurricane is intensifying, and to track its path. Since the ESSA operational satellite system came into being in 1966, no tropical storm has gone undetected, according to NESS.

Prior to the use of weather satellites, "surprise" hurricanes swept into inhabited areas, resulting in great loss of life and property. One storm that hit Texas at the turn of the century claimed 5,000 lives alone. Satellite data now lead to early detection of these storms over tropical oceans and to advance warning, lowering death tolls and property damage. Geosynchronous satellites are particularly important to storm tracking—it was largely through study of ATS 1 satellite photos of hurricane Camille in 1969 that NOAA was able to provide adequate warning to thousands of people living on the Mississippi gulf coast. When a hurricane is seen moving toward a given area, careful and precise tracking of the storm's path can also help prevent costly evacuation and protection operations in areas where, as it turns out, they are not needed. Satellites play a major role in keeping the warning areas to a minimum. A 1978 NESS report states that "as a conservative estimate, a reduction of only 5 percent in the coastal warning area would mean an average annual savings of about $2.5 million per year." [30]

Satellite weather bulletins are routinely sent to foreign meteorological agencies whenever a potentially threatening storm is spotted heading their way. As a result of satellite tracking, U.S. Government agencies have also been able to save the cost of airplane reconnaissance of hurricanes.

The prediction of tornadoes has been more difficult for meteorologists, partly because those storms are quicker developing and more short-lived. Still, high resolution visual and enhanced infrared imagery from the GOES satellites, taken at intervals of 15 minutes or less, have enabled forecasters to better pinpoint likely tornado spots.

---

[30] Hussey, W. John, and Heacock, E. Larry. "The Economic Benefits of Environmental Satellites." Washington D.C. National Environmental Satellite Service. National Oceanic and Atmospheric Administration, Department of Commerce. April 1978. p. 22.

Floods are another potentially destructive natural occurrence. Estimation of rainfall from GOES infrared cloud imagery and the mapping of snow cover by NOAA polar orbiters to predict spring snowmelts not only aid in flood warning, but also in water supply, irrigation and hydroelectric power management. It has been estimated that the cost ratio between satellite and conventional aerial mapping of snow cover is as much as 200 to 1 in favor of the satellite, and that annual savings in mapping the Sierra Nevada basins alone could be as much as $100,000 [31]

Satellite weather information is valuable to commercial and private aviators in many ways. Satellite-dependent forecasts are used as a matter of course by pilots in their preflight planning, especially for long distance flights, since the avoidance of major disturbances and storms is an obvious advantage for safe airplane flight. In 1977 the Federal Aviation Administration [FAA] initiated a program whereby air traffic controllers would routinely guide air traffic around severe weather as forecast with the aid of satellite data.

Similarly, a number of Latin American airlines regularly flying tropical routes, including LANCIA (Nicaragua), VARIG (Brazil) and Air Panama, initiated a program in 1977 to use satellite imagery for flight planning. Analysis of satellite weather images has been used to avoid extreme weather in some cases, and to use the winds around intense storm systems to advantage at other times. The analysis has even helped in planning of inflight meal times, when turbulence is at a minimum.

The Nimbus 7 satellite's Total Ozone Mapping Spectrometer was the key instrument in a 1981 experiment involving NASA, the FAA and Northwest Airlines to determine ozone levels in the atmosphere. The satellite data are intended to help commercial airlines avoid ozone concentrations, which can cause ear, eye, nose and throat irritation among passengers. Ozone levels are also an aid in determining the exact location of the jet streams that help airplanes save fuel and make better time in flight. Researchers envision a system which would provide the jet stream information directly to air-traffic controllers for improved route mapping.

Another aviation-related experiment was the Aircraft-to-Satellite-Data Relay [ASDAR] program conducted by NASA during the Global Weather Experiment in 1979. Several specially equipped commercial airplanes would transmit data on the weather around them—temperatures, wind speed and direction, etc.—up to synchronous satellites, which were then relayed to NOAA. Other planes could use this information in planning the best and most economical flying and tailwind conditions. The ASDAR experiment was deemed very successful and the World Meteorological Organization [WMO] has plans to make it into an operational system.

Search operations for missing or downed aircraft have also been greatly improved by the use of satellite data. As an example, satellite support of search and rescue missions by the California Civil

---

[31] Ibid. p. 16.

Air Patrol since 1976 has led to an average decrease of 62 percent in the number of hours flown per mission. Similar savings have been realized by the Aerospace Rescue and Recovery Service of the U.S. Air Force.[32]

The savings in fuel and time of operation of these search and rescue aircraft can be quantified, whereas the savings of lives as a result of quicker, more efficient rescues cannot.

The shipping industry uses forecasts of weather conditions over the oceans (largely determined by satellite data), in the same way as airlines—to plan safe, trouble-free routes. In addition, NOAA satellite infrared measurements of sea surface temperatures can be used to determine the exact locations of swift-moving currents that constantly change their position. A 1975 experiment conducted jointly by NOAA and the Exxon Corp. led to the estimate that Exxon alone might save $360,000 in fuel costs each year by having tankers hitch rides on the Gulf Stream northbound and avoid it on southern trips.[33]

Polar orbiters also provide valuable data on sea ice conditions, especially in the Arctic regions. Sea ice observations have helped to plot shipping routes in the Great Lakes region, and have allowed shipping lanes to stay open for longer periods each year, resulting in estimated annual savings of $30 to $60 million.[34]

Sea ice measurements by NOAA satellite AVHRR equipment are used for yet another purpose by offshore oil and gas drillers in Alaska, who monitor the satellite images of ice floes to determine potential danger to rigs.

The U.S. fishing industry saves much fuel and time by using satellite infrared imagery of "thermal fronts" in coastal waters. These fronts—showing water temperature difference at the ocean surface—are valuable tools in predicting where certain commercially valuable fish are going to be. Time spent looking around for fish is thus converted to time spent catching them. Crab fishermen in the southern Bering Sea, after losing $3 million in 1980 because of ice formations ruining their crab pots, have learned to use satellite data to retrieve the pots before ice forms.

A study published in 1973 by the Space Science and Engineering Center of the University of Wisconsin showed that improved weather information and forecasting could also provide large economic benefits to the agriculture industry, and that improved weather information would have saved crop growers and processors $74 million in 1971.[35]

The greatest gains would be for those growing such crops as citrus fruits, apples, cotton, rice, and sugar beets. The Hawaiian sugar cane industry greatly benefits from satellite weather forecasting, since the crop is burned just before harvest, and the burning operations must take place under certain wind and rainfall conditions.

Benefits to the Florida citrus fruit crop are especially well documented. By advising growers of impending frosts, satellite-dependent forecasting have been able to be more precise about the likelihood of freezing weather. Growers can thus limit expensive heating operations only to the times when they are definitely needed. This yields an estimated annual savings potential of $48 million.[36]

---

[32] McClain, E. Paul. Environmental Satellites, McGraw Hill Encyclopedia of Environmental Science, New York. 1980.

[33] Hussey and Heacock. op. cit. p. 7

[34] Ibid. p. 13

[35] Ibid.

While it is difficult to quantify, it can be said also that the meteorological satellite program has had the indirect result of strengthening international ties, through such programs as the World Weather Watch and the supplying of storm warnings by the United States to foreign countries. In the opinion of George Benton, former president of the American Meteorological Society and past director of the Environmental Research Laboratory:

> Countries all over the world interrogate our satellite as it passes overhead, and obtain images which show the distribution of clouds and weather over and near their territory. These images are of vital importance to many developing nations, which have only primitive weather observing systems.
>
> Weather satellites have been one of the major successes of the space age. In addition to the value of the satellites to the meteorological and hydrological services of the United States, the orbiters have contributed substantially to world cooperation and stability.[37]

---

[36] Ibid., p. 8

[37] Benton, op. cit.

CHAPTER FIVE

EARTH RESOURCES AND ENVIRONMENTAL MONITORING SATELLITES

I. LANDSAT

A. INTRODUCTION

Early in the U.S. manned space flight program, astronauts using hand-held cameras photographed the Earth from the windows of their spacecraft. These broad synoptic views provided a new way to examine the Earth and were received with a high degree of interest. Concurrently, new types of high altitude imagery using multispectral scanners [MSS] were developed and tested using aircraft. These two activities resulted in a concept of a new global data acquisition system consisting of an MSS mounted on a satellite observation platform, a concept that ultimately become known as Landsat.

Landsat 1 was launched on July 23, 1972, followed by Landsat 2 on January 22, 1975 and Landsat 3 on March 5, 1978. Landsat 1 was retired from service on January 16, 1978 after exceeding its design life by 4½ years. Landsats 2 and 3 continue to return data at the end of 1981, but both have encountered problems. Landsat D, the next in the series, is scheduled for launch in July 1982 and will carry a new instrument, called a Thematic Mapper [TM], in addition to a four-band MSS. The TM will have a better ability to resolve images, and a much higher data rate. A backup spacecraft, called Landsat D′ (D prime), will be launched in 1985 unless problems develop with Landsat D (the two spacecraft are identical). No further spacecraft are planned at the present time, although NASA is developing remote sensing experiments which will fly on the space shuttle.

The Landsat program continues to face problems in both the domestic and international spheres. The primary domestic question concerns what will happen to the Landsat program after D′ is launched, in terms of how to move the system from experimental to operational status (especially whether it should be operated by the Government or private sector). Internationally, issues concerning who owns the data returned from remote sensing satellites (the country who operates the satellite or the country that has been sensed) and whether remote sensing satellites should be managed by an international body such as the United Nations, remain unresolved after more than a decade of debate.

B. THE LANDSAT PROGRAM

1. The spacecraft

Landsat spacecraft orbit the Earth at an altitude of 917 kilometers (570 miles) approximately once every 103 minutes, or 14 times a day. On each orbit, the satellite views a different 185 kilometer (115 mile) strip of the Earth running north/south from pole to pole. After 18 days, the satellite has viewed every place on Earth at least once. If two Landsats are in operation, the cycle repeats itself every 9 days.

Since uniform lighting is important for consistent data interpretation, sun-synchronous, near-polar orbits were chosen. The satellites therefore cross the Equator at the same time each day, viewing any given area at approximately 09:42 a.m. local time.

Table 5-1 summarizes the characteristics of Landsats 1-3 and Landsat D (Landsat D′ is the same as Landsat D).

TABLE 5-1

LANDSAT SPACECRAFT CHARACTERISTICS

	LANDSAT 1	LANDSAT 2	LANDSAT 3	LANDSAT D
Launch Date	July 23, 1972	Jan. 22, 1975	Mar. 5, 1978	July 1982?
Design Life	1 year	1 year	1 year	3 years
Orbit				
Altitude	917 kilometers	917 kilometers	917 kilometers	705 kilometers
Equatorial Crossing	9:30 a.m.	9:30 a.m.	9:30 a.m.	9:30 a.m.
Repetitive Coverage	18 day	18 day	18 day	16 day
Instruments				
RBV	X	X	X	
MSS				
Resolution	80 meter	80 meter	80 meter (Bands 1-4) 240 meter (Band 5)	80 meter
Bands	4	4	5	4
Data Rate	15 Mbps	15 Mbps	15 Mbps	15 Mbps
Scenes/Day	170	200	200	200
TM				
Resolution				30 meter
Bands				7
Data Rate				85 Mbps
Scenes/Day				100
Data				
On-Board Storage	X	X	X	
Downlink	Domestic Readout	Domestic Readout	Domestic Readout	TDRSS and directly to ground
Foreign Stations Operating At Launch	0	3	5	10-12
Status As Of December 31, 1981	Operations Terminated	Operating; Tape Recorders Inoperative	Operating Partially; 1 Tape Recorder Inoperative; Band 5 Inoperative	Scheduled for July 1982 launch

Source: NASA

2. Landsats 1-3

The Landsat spacecraft are patterned after the Nimbus meteorological satellite (described in chapter 4). The satellites weigh 953 kilograms (2,100 pounds) and have an approximate overall height of 3.04 meters (10 feet) and a diameter of 1.52 meters (5 feet), with solar panels extending out out to a total of 3.96 meters (13 feet).[1] Spacecraft attitude is controlled with a pointing accuracy of less than 0.7 degrees in all three axes (roll, pitch, and yaw). Two wideband video tape recorders store up to 30 minutes each of picture information for readout when the spacecraft is in view of a data acquisition station on the ground.

Landsat satellites carry a return beam vidicon [RBV] subsystem, multispectral scanners [MSS], and a data collection subsystem [DCS]. The RBV and MSS provide independent images of the same 185 by 185 kilometer (115 by 115 mile) area of Earth in various spectral bands. The DCS collects and relays data from remotely located ground platforms to the Landsat data acquisition stations.

a. Return Beam Vidicon Subsystem.—RBV cameras are used to view the same ground scene as the MSS, but are sensitive to different spectral bands. On Landsat 1 and 2, three RBVs were used to scan in the following spectral bands: 0.475 to 0.575 microns; 0.580 to 0.680 microns; and 0.690 to 0.830 microns. Landsat 3 carries two RBV scanners, both in the band 0.505 to 0.750 microns.

When the cameras are shuttered, images are stored on photosensitive surfaces within each vidicon camera tube; the tubes are then scanned to produce video outputs. The cameras scan in sequence, requiring about 3.5 seconds to read out each of the three images. To produce overlapping images of the ground along the direction of spacecraft motion, the cameras are reshuttered every 25 seconds. Full color images can be produced when each of the separate images is processed and superimposed in its respective color on a single frame. The resolution of the RBVs for Landsat 1 and 2 is 70-80 meters, while for Landsat 3 it is 26-40 meters, depending on exposure time. On Landsat 3, RBV scenes are only one-quarter the size of an MSS scene, so four subscenes are needed to provide the same coverage as the MSS.

b. Multispectral Scanners.—Different materials on the Earth's surface absorb and reflect sunlight differently. For example, the wavelength at which the Sun's energy is absorbed by a plant for growth is dependent upon the plant type, plant maturity, and overall condition. It is therefore possible to determine the identity and condition of plants by the unique way in which they reflect energy from the Sun. The MSS measure this reflected energy, which is then sent to Earth in the form of digital data.

On Landsat 1 and 2, the MSS could scan in four different wavelengths: 0.5-0.6 microns; 0.6-0.7 microns; and 0.8-1.1 microns. A fifth band for measuring thermal (infrared) radiation was added to Landsat 3 at 10.4-12.6 microns, but this channel did not work properly.

---

[1] Technical information was provided by NASA.

Scanning is achieved by means of a mechanically oscillating mirror that flips from side to side about 13 times a second as the spacecraft progresses around Earth in its orbital path.

MSS image resolution is 80 meters for the four bands, and 240 meters for the fifth band on Landsat 3.

c. Data Collection System.—The data collection subsystem (DCS) aboard Landsat collects and relays data from up to 1,000 sensor-platforms located in remote areas throughout the United States to the Landsat data acquisition stations. Data are transmitted twice a day from each platform when the spacecraft is in simultaneous view of the transmitting platform and a data acquisition station. Each DCS platform collects data from as many as eight sensors, sampling such local environmental conditions as temperature, stream flow, snow depth, or soil moisture. Data from all platform are relayed to the Goddard Space Flight Center in Greenbelt, Maryland and can be available to investigators within 24 hours after collection.

d. Spacecraft Status.—Landsat 1, launched on July 23, 1972, outlived its design life by four and a half years and was finally retired on January 16, 1978.[2] Its tape recorders had long since ceased functioning (the first in August 1972, the second in July 1974), and control problems had developed with the mechanism that kept the satellite pointed toward Earth (the pitch wheel). The satellite provided more than 300,000 pictures of the Earth.

Landsat 2 was launched on January 22, 1975 and at the end of 1981 was still returning data, although both of its tape recorders have failed (the first on January 26, 1977 and the second on May 21, 1981), meaning that data can only be acquired while that spacecraft is in view of a ground receiving station. Landsat 2 also experienced control problems (a rotating flywheel became jammed due to degraded lubrication) that led to its being retired from service on the fifth anniversary of its launch on January 22, 1980.[3] Engineers were able to devise an alternative method for stabilizing the satellite, using a magnetic compensation system, and it was returned to operational status in July 1980. During experiments with the magnetic system, the flywheel which had been stuck began operating again, but the magnetic system was still required to maintain the roll and yaw axes in a safe range. The control problems reappeared at the end of 1981, and the future of the satellite was gloomy as the year drew to a close.

Landsat 3 launched on March 5, 1978 and was still returning partial data at the end of 1981 (one of the tape recorders failed on June 5, 1979). Problems developed in the MSS shortly after launch. The fifth band added to the MSS (the thermal band) worked for only a short time because of a design flaw in the cooling unit required for that band. The band had two detector channels—one for scanning across the flight path of the spacecraft and one for scanning along it; the one which was designed to scan along the flight path failed. As a result, every other line in any image was missing. Only a limited amount of data was collected with the sensor for experimental purposes.

---

[2] Landsat 1 Earth resources satellite is retired. NASA press release 78-9.

[3] Landsat 2 ceases operations. NASA press release 80-9. Jan. 22, 1980.

In the fall of 1978, another MSS problem developed with the way in which the scan lines are broken down for the other four bands. The problem was circumvented by switching to a backup system, but that developed the same problem in May 1979. The scanner builds up an image from swings of the oscillating mirror (described earlier). The data bits would form one continuous line if they were not then broken down and printed under each other to form a rectangular picture. Start and end pulses are used to tell the scanner where to break the line. The line scan monitor is not inserting the start pulses correctly, and some of the lines are offset by about 25 percent (a backup system inserts a start signal 25 percent of the way across the line, thus saving the other 75 percent). Some of the pictures are not affected at all, some have 5 percent of the lines offset, and some have as much as 40 percent of the line offset. Images taken between the 35° north and south latitude are affected the most.

3. Landsat D and D'

Landsat D, the next in the series, is scheduled for launch in July 1982. An identical backup satellite, designated D' (D prime), is scheduled for launch in 1985 unless Landsat D fails prematurely.

These satellites will carry an MSS as well as an improved scanner called the Thematic Mapper (TM).[4] The TM can sense data in seven spectral bands: Band 1—0.76 to 0.9 microns; Band 2—0.63 to 0.69 microns; Band 3—0.52 to 0.6 microns; Band 4—0.45 to 0.52 microns; Band 5—1.55 to 1.75 microns; Band 6—10.4 to 12.5 microns, and Band 7—2.08 to 2.35 microns. An aircraft-mounted TM simulator has been used to test the effectiveness of the band and resolution selections for this instrument.

Landsat D will be placed in a lower orbit than its predecessors: 700 kilometers instead of 917 kilometers. Coupled with the advanced instrumentation of the TM, image resoluton will be 30 meters, or about one-fifth of an acre (compared to 80 meter, or 1.2 acre resolution with the MSS) for the bands 1-5 and 7; the sixth band has a resolution of 120 meters. (Bands 1-5 and 7 contain 16 detectors, while Band 6, for thermal radiation, has only 4). In addition, the data rate of the TM will be 110 megabits per second (mbps), versus 15 mbps on the MSS. NASA expects the TM to provide ten times the data of the MSS. The MSS is being included on the satellites to provide continuity to users of the data, and since the TM carries the thermal band, it has only the four bands used on Landsats 1 and 2.

Landsat D and D' do not carry tape recorders like the earlier satellites, because they can continuously relay data directly to ground stations or through the Tracking and Data Relay Satellite [TDRSS] to the ground.[5]

The issue of whether or not to include an MSS on Landsat D and D' was a matter of dispute during consideration of NASA's fiscal year 1978 budget request. The Office of Management and Budget

---

[4] The name "thematic mapper" was chosen to describe the way in which the data will be used to more narrowly categorize crops, geologic formations, etc., into groups or "themes." The instrument itself is simply an uprated multispectral scanner.

[5] See chapter 9 for a discussion of TDRSS.

[OMB] felt that sufficient experience had been gained with the MSS instrument so that no further research and development flights were required and rejected NASA's request for funding to include an MSS. NASA and the user community wanted the MSS on board to provide for a transition period between using MSS and TM data, but NASA was unable to get money from the user community to pay for it.[6]

In acting on the budget request, Congress authorized NASA to allocate $2 million of its fiscal year 1978 funding to provide an MSS on the spacecraft.[7] A committee was formed by the President's Science Adviser, Frank Press, to assess the need for the MSS, and it concluded that the instrument should be carried.[8] With Congress and the administration supporting inclusion of the MSS, the instrument was approved.

Ironically, difficulties encountered in developing the TM during 1979 and 1980 almost forced NASA to drop the TM from the spacecraft and fly only the MSS. The original launch date for Landsat D was to have been September 1981, a date which NASA felt had to be kept in order to assure continuity of data flow to users, as well as to allow for an orderly transition of the system from experimental to operational status. In October 1979, NASA's Associate Administrator for Space and Terrestrial Applications, Anthony Calio, reported to the House Science and Technology Committee that he was "not optimistic" that the prime contractor for the TM (Hughes Aircraft) would be able to meet the September 1981 deadline for delivery of the first TM, and alerted the committee to the possibility that the launch date might slip. The problem was attributed to poor management by the prime contractor.[9] The cost of the TM, originally estimated at $38 million, rose to $85–90 million during this period (for two flight models).

In April 1980, NASA announced that it was studying various options for restructuring the Landsat D program because of increasing engineering and managerial problems encountered in the manufacture of the spacecraft's instrument and ground systems. The three options considered by the agency were to: launch Landsat D with both the TM and MSS as soon as possible; launch Landsat D as soon as possible with only the MSS, to be followed as soon as possible by Landsat D' with both instruments; and to launch Landsat D and D' only with MSS instruments.[10]

In September 1980, NASA reported to Congress that the launch date for Landsat D would be slipped to the second half of 1982, while asserting that the TM would not be allowed to pace the program. With or without that instrument, the spacecraft would be launched. NASA added that the outlook for the TM was getting brighter.[11]

---

[6] "NASA Plans No Multispectral Scanner for LANDSAT-D, Weighs Need." Aerospace Daily, Feb. 3, 1977, pp. 174–5.

[7] U.S. Congress. Committee of Conference. National Aeronautics and Space Administration authorization, fiscal year 1978. 95th Congress, 1st session. H. Rept. 95–448. Washington, U.S. Government Printing Office, June 21, 1977. p. 8.

[8] "Multispectral Scanner Urged for Landsat D." Aviation Week & Space Technology, Dec. 5, 1977, p. 49.

[9] U.S. Congress. House. Committee on Science and Technology. Subcommittee on Space Science and Applications. 1981 NASA authorization (program review). 96th Congress, 1st session. Oct. 16, 17, 18, 1979. Washington, U.S. Government Printing Office, 1979. p. 16.

[10] "NASA Considers Options for Restructuring Landsat-D Program." NASA news release 80-46, Apr. 14, 1980. 3 pp.

The TM for Landsat D was delivered to NASA on September 30, 1981 (the second is expected to be delivered in October 1982). The final cost for the two TMs is $120 million.[12]

Initially, NASA will acquire only one scene per day from the TM because the processing system for the data will not be completely ready until mid-1983. After that time, 12 scenes per day will be obtained for an additional experimental period, with 100 scenes per day expected to be acquired once the TM is operational in 1985. In addition, since the Tracking and Data Relay Satellite System will not be in orbit until early 1983, initial TM data will only cover the eastern part of the United States where it can be relayed directly to Goddard Space Flight Center (other Landsat receiving stations do not yet have the capability to receive the high data rates required with TM).

4. Program costs

Through the end of fiscal year 1981, NASA had spent $827 million on the Landsat program. Fiscal year 1982 funding was expected to be $83.9 million, while the National Oceanic and Atmospheric Administration [NOAA] which will take over operation of the Landsat system in January 1983 (see below), was expected to spend $1.1 million on Landsat in fiscal year 1982.

Table 5-2 provides a breakdown of NASA funding for the Landsat program.

---

[11] U.S. Congress. House. Committee on Science and Technology. Subcommittee on Space Science and Applications. 1981 NASA authorization (program review). 96th Congress, 2d session. Sept. 16, 17, 18, 1980. Washington, U.S. Government Printing Office, 1981, p. 310.

[12] NASA Office of Congressional Affairs, June 1982.

TABLE 5-2

NASA FUNDING FOR THE LANDSAT PROGRAM
(in $ millions)

	Through FY81	FY82 Estimate	FY83 Request
DEVELOPMENT			
Landsat 1 & 2	$187.3*	—	--
Landsat 3	$ 43.8	—	--
Landsat D & D'	$344.6	$ 83.9	$ 61.7
OPERATIONS			
Landsat 1	*	*	*
Landsat 2 & 3	$ 2.0	$ 2.6	$ 1.7
Landsat D & D'	**	**	**

---

* Figures for development and operations for Landsat 1 were not maintained separately by NASA.

** Landsat D and D' operations will be funded by the National Oceanic and Atmospheric Administration

Source: NASA Office of Legislative Affairs, June 1982.

C. USING LANDSAT DATA

1. Advantages of remote sensing data from satellites

The accuracy of data acquired from remote sensing satellites is for the most part dependent upon good supporting surface measurements (ground truth). Satellite information generally cannot stand alone without good ground truth data. Thus, satellite data is valuable not for replacing in-situ measurements, but for generalizing these measurements to areas so vast (country or regional scale) that conventional techniques cannot provide the integrating information at less than exorbitant costs. In general terms, satellite imagery has a 20:1 cost advantage over other methods of obtaining such data.[13] Also, each Landsat picture covers 34,000 square kilometers or an area 185 by 185 kilometers. Thus, less than 600 Landsat images are required to cover the United States, compared to 500,000 photographs from high altitude aircraft.

The interpretation of satellite data is also less time-consuming than the interpretation of data derived from traditional survey techniques. This increase in the speed of data interpretation and repetitive coverage enables the user to effectively monitor such constantly changing phenomena as crop growth. As one of its earliest applications, investigators employed Landsat 1 data to furnish information needed to curb the cotton bollworm in a 320,000 hectare (800,000 acre) cotton field in California's Imperial Valley. The most effective method of curbing this past is by the timely uprooting of cotton plants. This requires tight scheduling: the cotton must be harvested as soon as it has matured, and then the plants must be promptly plowed under. To accomplish this, farmers must closely monitor the status of crop growth. Landsat 1 investigators provided a complete inventory of crop status in 16 person-hours, compared to 128 person-hours that would have been required using traditional methods.[14]

2. Users of Landsat data

Landsat data are used by Federal, State, and local governments, as well as by the private sector and foreign countries. In the nearly 10 years that Landsat data have been available, a wide variety of applications have developed. Specific examples have been presented in many other publications and need not be repeated here.[15]

In general, Landsat data has been used for applications such as agriculture (particularly crop forecasting), forestry, fishing, mineral exploration, land and water resource management, hydrology, geology and mapping, pollution monitoring, and coastal zone management.

---

[13] James Welch, NASA Office of Space Science and Applications, private communication, June 1982.

[14] Lani H. Raleigh. "Specific International Applications Satellite Programs." In: World-Wide Space Activities. Committee print. Prepared for the House Committee on Science and Technology by the Science Policy Research Division of the Congressional Research Service. Washington, U.S. Government Printing Office, 1977. p. 439.

[15] For example, see: Raleigh, ibid., pp. 449 ff; Barry S. Siegal and Alan R. Gillespie, eds. "Remote Sensing in Geology." New York, John Wiley & Sons, 1980; William L. Smith, ed. "Remote-Sensing Applications for Mineral Exploration." Stroudsburg, Pa., Dowden, Hutchinson & Ross, Inc., 1977.

NASA established three Regional Application Centers [RACs] in 1978 to assist State and local governments in utilizing satellite remote sensing data. The RACs are located at three NASA field centers: Goddard Space Flight Center in Maryland, the National Space Technology Laboratories in Mississippi, and Ames Research Center in California. By May 1981, 26 States had developed operational capabilities for using Landsat data.[16] These activities are funded through NASA's technology transfer program. NASA, through its International Affairs office, and the Agency for International Development have sponsored programs to assist foreign countries in utilizing Landsat data (discussed in section E).

In early 1982, Metrics, Inc., of Atlanta, Ga., released a worldwide market study for satellite remote sensing services which estimated that hardware procurement would rise from the current annual level of $45 million to $150 million by 1990, and data services would rise from $38 million to more than $150 million annually.[17]

One method of assessing the use of Landsat data is to look at the amount of data purchased by various classes of users. Table 5-3 provides a customer profile by dollar value of Landsat data purchases; data was taken from the EROS Data Center's Landsat data users notes for January 1982.

---

[16] Paul A. Tessar, Loyola M. Caron, and Jane Germano. "A Survey of State Applications of, and Investments in, Landsat Technology." Denver, National Conference on State Legislatures, May 1, 1981. p. vii.

[17] Aviation Week and Space Technology, Feb. 8, 1982, p. 13.

TABLE 5-3

USERS OF LANDSAT DATA: FY 1977-1981

	FY77	FY78	FY79	FY80	FY81
Dollar Volume of Total Landsat Sales	$1,453,837	$1,976,068	$2,131,813	$2,388,567	$2,495,268
Category of User					
Federal Government	26%	31%	23%	16%	19%
State/Local Government	1%	1%	1%	3%	4%
Academic	10%	8%	11%	9%	8%
Industrial	28%	24%	24%	26%	31%
Individual	5%	4%	5%	4%	5%
Non-U.S.	30%	32%	36%	42%	33%

Source: EROS Data Center. Landsat Data Users Notes, January 1982, p. 12.

3. Availability and cost of Landsat data

U.S. policy regarding access to data from the Landsat program is that it is available to everyone. This is termed the "open skies" policy and is not accepted as a worldwide standard. The international debate over this issue is reviewed in section E.

In the United States, Landsat data are processed initially at NASA's Goddard Space Flight Center. Master copies of all data are sent to the Earth Resources Observation System [EROS] Data Center, which is operated by the Department of the Interior at Sioux Falls, S. Dak. (NOAA will take over some of these activities when it accepts responsibility for the Landsat program in January 1983—see section D). These data are stored, reproduced, and disseminated to the general public on demand for a fee. The United States, through NASA, the Departments of State and Interior, has or had cooperative programs with over 50 countries for utilizing Landsat data. There are also a number of foreign Landsat ground stations which acquire their own data from the spacecraft (see section E).

A major problem encountered with the availability of data has been the amount of time required for a user to get it. At one time, there was a backlog of as many as 6 months for obtaining the data, although by the end of 1981, this had been reduced to a 2-week wait. With Landsat D and its interface with the Tracking and Data Relay Satellite, NOAA expects to provide data within 48 hours.

The cost of the data has increased over the years. Initially, the price reflected only the direct costs associated with processing, reproduction, and distribution of the data products. In January 1977, however, new prices were established to reflect overhead costs (such as packaging and mailing) as well.

In December 1981, NOAA announced that prices for Landsat products and services would increase again as of October 1, 1982. Prices will go up about two and one-half times their previous level. NOAA explained the cost increase as resulting from the decision that "users bear the costs of operating and maintaining the operational NOAA Landsat-D system through the fees they pay for the products and services provided by the system." [18]

Data are available in several different forms—film positives, film negatives, paper, microfilm, slides, and computer compatible tapes—and prices will range from $4 for a 35-mm slide from the existing collection of images, to $1,300 for a computer compatible tape of four subscenes from the RBV's.

4. U.S. Government programs for demonstrating utility of Landsat data

As outlined previously, Landsat data are used by Federal, State, and local governments, as well as by the private sector and foreign countries. Two programs have been sponsored by the Federal Government to demonstrate the utility of Landsat data for agricultural applications; a third, for geological applications, was planned but has been subsequently cancelled.

As discussed elsewhere in this chapter, the future of the Landsat program is uncertain at this time because of questions concerning transfer of the operational Landsat from the Government to the private sector. Another component of the debate concerns the future of these Government-sponsored programs to demonstrate the utility of Landsat data. The tri-agency LACIE program was successfully concluded during the 1970's, but its follow-on effort, AgRISTARS, is now in jeopardy because of budget constraints. The GAP program for geological applications has been cancelled for the same reason.

a. *Large Area Crop Inventory Experiment [LACIE].*—Remote sensing for agricultural purposes began in the 1960's using photographs from aircraft. This later developed into multispectral imagery from aircraft, and eventually, multispectral imagery from satellites.

Investigators using Landsat 1 images of California's Imperial Valley in 1972–73 inventoried more than 25 separate crops in 8,865 fields (458,800 acres) in 40 person-hours. Among the crops readily identified were corn, popcorn, soybeans, sorghum, oats, grasses, lettuce, mustard, tomatoes, carrots, onions, and alfalfa. Scientists could distinguish between wet-planted fields, plowed lands, harvested fields, and bare soil in areas as small as 10 acres.[19]

---

[18] "Information Update for Users of NOAA/NESS Satellite Data." NOAA press release, December 1981.

This experiment demonstrated the potential of satellite systems for making accurate, extensive, and repeated crop surveys and led to a larger experiment known as the Large Area Crop Inventory Experiment [LACIE]. The LACIE program ran from 1974 to 1978 and was jointly sponsored by NASA, the Department of Agriculture [USDA], and the National Oceanic and Atmospheric Administration [NOAA]. Total program costs were $50.3 million ($37.7 million from NASA, $9.6 million from USDA, and $3 million from NOAA).

The LACIE program was designed to demonstrate the capability of using remote sensing techniques and data processing systems in combination with more conventional techniques to improve the speed and accuracy of global crop forecasts. Wheat was selected as the sample crop because it is the most important internationally traded crop, is grown in a wide variety of regions throughout the world with differing climates, and is fairly well understood in terms of its spectral characteristics.[20]

The three major goals of the LACIE program were: (1) to achieve an accuracy such that at-harvest estimates be within 10 percent of the true estimate at the national level 90 percent of the time (this became known as the 90/90 criterion); (2) to establish the feasibility of acquiring and analyzing Landsat data within a 15-day interval; and (3) to determine how early in the crop year accurate estimates could be produced.[21]

The program was conducted in three phases. Phase I, from 1974–75, involved testing the system over the U.S. Great Plains where ground truth data could be easily provided to verify the accuracy of LACIE predictions. In Phase II, from 1975–76, the test area was expanded to cover Canada and two regions in the Soviet Union, as well as the Great Plains. In Phase III, from 1976–77, the area was broadened again to include all of the wheat growing regions of the Soviet Union, Australia, China, India, Brazil, and Argentina.[22]

LACIE results were mixed, improving as the program progressed. For Phase I, although LACIE provided estimates for winter wheat that were within 5 percent of the USDA estimate, the production estimate for spring wheat was about 25 percent lower than USDA's. The problem with estimating spring wheat production rested with technical difficulties in distinguishing between newly planted wheat and other spring grains. Thus LACIE underestimated the spring wheat acreage. Nevertheless, the combined accuracy for spring and winter wheat estimated fell within the desired accuracy for the program.[23]

---

[19] Stanley C. Freden, Enrico P. Mercanti, and Donald E. Witten, eds. Symposium on Significant Results Obtained from Earth Resources Technology Satellite—1. Vol. II: Summary of Results. Greenbelt, Md., NASA Goddard Space Flight Center, May 1973. X–650–73–127. p. 74.

[20] U.S. Congress. House. Committee on Science and Technology. Subcommittee on Space Science and Applications. 1978 NASA authorization. Hearings, 95th Congress, 1st session. Feb. 2, 4, 5, 6, 7, 9, 1977. Washington, U.S. Government Printing Office, 1977. p. 404.

[21] R. Bryan Erb. "An Overview of the Large Area Crop Inventory Experiment and the Outlook for a Satellite Crop Inventory." Presented to the First Brazilian Remote Sensing Symposium, Sao Jose dos Campos, Brazil, Nov. 27–29, 1978. Houston, Tex., NASA Johnson Space Center, March 1979. JSC–13761.

[22] Ibid.

In Phase II, according to NASA, LACIE estimates "marginally missed" the 90/90 criterion for the Great Plains, met the 90/90 criterion for the Soviet Union, and missed it for Canada because the spring wheat acreage was underestimated.[24] Regarding the NASA estimates of accuracy for the Soviet Union, the General Accounting Office [GAO] noted that LACIE projections overestimated acreage by about 12 percent and underestimated production by about 15 percent for winter and spring wheat combined, so the 90/90 accuracy was achieved only because of offsetting errors in the LACIE area and yield estimates.[25]

In Phase III, coverage of the LACIE Program was reduced to detailed study of the United States and Soviet Union, with only a small amount of effort devoted to the other countries that were supposed to be part of the study. This reduction in scope was taken so that more time could be devoted to resolving technical problems in meeting LACIE's goals, especially in distinguishing between spring wheat and other grains.

Some of the problems encountered during Phase II were remedied by the time Phase III took place, and overall the results were good. A NASA press release noted that LACIE predicted a production of 91.4 million metric tons for the Soviet Union, compared with the official production estimates of 92 million metric tons, less than a 1 percent difference. The agency cautioned that "the capability to achieve such accuracy from year to year has yet to be demonstrated," however.[26]

NASA and GAO noted that the improved sensors on Landsat D would provide increased sensitivity and higher resolution which could aid in distinguishing between spring wheat and other grains.[27]

Dr. Don Paarlberg, former Director of Economics for USDA, chaired a peer evaluation team to review the LACIE techniques. The report concluded that LACIE results "clearly demonstrate that present remote-sensing capabilities can be combined with or substituted for conventional methods of information collection in order to improve foreign crop production estimates." The report added that in some areas, such as the Soviet Union, LACIE technology was ready to be made operational, while "for regions where the technology requires improvement, funding for further research and development should be continued."[28]

b. Agriculture and resources inventory surveys through aerospace remote sensing [AgRISTARS].—Originally, USDA planned to implement an operational version of LACIE once the experiment program was completed. In 1977, however, USDA decided that a one-crop system was insufficient, and chose instead to pursue another technology development program with a broader scope. A USDA task force identified seven areas where information was needed that aerospace technology could wholly or partially satisfy. Known as the Secretary of Agriculture's initiative, these areas became the basis for the AgRISTARS program.[29]

---

[23] U.S. General Accounting Office. "Crop Forecasting by Satellite: Progress and Problems;" report to the Congress by the Comptroller General. Washington, U.S. GAO, Apr. 7, 1978, PSAD-78-52. p. 7.

[24] 1978 NASA authorization hearings, op. cit., p. 414.

[25] GAO, op. cit., p. 8.

[26] "Global Crop Experiment Evaluated." NASA press release 78-179, Nov. 17, 1978.

[27] 1978 NASA authorization hearings, op. cit., p. 420. GAO report, op. cit., p. 20.

[28] NASA press release, op. cit., p. 4.

1. Early warning of changes affecting production and quality of commodities and renewable resources;
2. Commodity production forecasts;
3. Land use classification and measurement;
4. Renewable resources inventory and assessment;
5. Land productivity estimates;
6. Conservation practices assessment; and
7. Pollution detection and impact evaluation.

In February 1978, the three agencies which had been involved with LACIE [USDA, NASA and NOAA] met with the Department of the Interior and the Agency for International Development [AID] to discuss the possible development of a program based on the Secretary's initiative. A joint planning team drew up a proposal for a 6 year program (from fiscal year 1980 through fiscal year 1985), costing $317.3 million ($173.3 million from NASA, $124.2 million from USDA, and $19.8 million from NOAA—the other two agencies were involved only in evaluating the utility of AgRISTARS products for their missions). An interagency agreement was written, and went into effect in January 1980 (AID did not sign the agreement because it felt its proper role was as an observer).[30]

The program was organized into eight projects: (1) early warning crop condition assessment; (2) foreign commodity production forecast; (3) yield model development; (4) supporting research; (5) soil moisture; (6) domestic crops and land cover; (7) renewable resources inventory; and (8) conservation and pollution. NASA was designated the lead agency for projects 2 and 4, NOAA for project 3, and USDA for the remainder of the projects as well as for the entire AgRISTARS program.

In April 1979, after initial funding for AgRISTARS had been requested as part of the fiscal year 1980 budget, the Senate Appropriations Committee requested its investigations staff to assess the AgRISTARS program proposal. The interagency agreement for the program had not been signed at this point, and the committee wanted an assessment of the program "to determine requirements, coordination with other Federal agencies, costs (USDA and all other agencies), program schedules, management, milestones, and feasibility."[31]

In its June 1979 report, the investigations staff was highly critical of certain aspects of the AgRISTARS program, particularly those relating to foreign commodity production forecasting (which the staff identified as projects 2, 4, and part of 3). Arguing that

---

[29] U.S. Department of Agriculture. Secretary's Initiative. Joint program of research and development of uses of aerospace technology for agricultural programs. Feb. 3, 1978. [n.p.]

[30] Interagency agreement among the U.S. Department of Agriculture, U.S. Department of Commerce, U.S. Department of the Interior, National Aeronautics and Space Administration, and the Agency for International Development for a joint program for agriculture and resources inventory surveys through aerospace remote sensing (AgRISTARS). 5 pp. Effective Jan. 16, 1980.

[31] Investigations staff, Committee on Appropriations, U.S. Senate. Proposed joint project for agriculture and resources inventory surveys through aerospace remote sensing (AgRISTARS). Submitted to the Subcommittee on Agriculture, Rural Development, and Related Agencies, the Subcommittee on HUD-Independent Agencies, and the Subcommittee on State, Justice, Commerce, the Judiciary. Report No. 79-5. June 1979.

LACIE results had been poor, the investigations staff stated that the problems encountered in that program would be compounded when the same techniques were applied to other crops such as corn and soybeans, which are difficult to separate spectrally. The staff also commented that the yield models used for LACIE had been found to be severely limited, such that USDA was proposing over $50 million for R&D on new types of yield models in another segment of the AgRISTARS project, but that these new models would not be available for the commodity production forecasting project. Thus, the staff recommended that funding for that segment of AgRISTARS be denied. For the other segments of the program, the staff stated that cost-benefit analyses had not been conducted, and that the Committee on Appropriations might want to make such analyses a prerequisite for continued funding of AgRISTARS.[32]

The agencies responded to the questions raised by the investigations staff, and funding for the program was approved in fiscal year 1980 and fiscal year 1981. In January 1982, the involved agencies published an annual report detailing the accomplishments of the program to date.[33]

In fiscal year 1982, however, budgetary problems began impacting the program. The budget revision for fiscal year 1982 submitted by President Reagan shortly after he took office proposed that NASA's budget for AgRISTARS be reduced by $10 million in both fiscal year 1981 and fiscal year 1982. Since the program calls for pilot experiments to be conducted by NASA, followed by USDA applications tests, a slowing down of NASA's activities would affect the rest of the program. The revised NASA budget figures included stretching out the program by 2 years, to fiscal year 1987. NASA's funding history for the AgRISTARS program is shown in table 5-4. Although Congress appropriated the Reagan request of $23.1 million for fiscal year 1982, the NASA operating plan for fiscal year 1982 includes only $14.0 million for AgRISTARS.

The NOAA and USDA budgets for AgRISTARS are not identified separately in the budget requests of those agencies. NOAA has spent approximately $2.5 million per year on the program,[34] while USDA spent $10.8 million in fiscal year 1980 and $12.8 million in fiscal year 1981 and expects to spend $12.5 million in fiscal year 1982 and $12.6 million in fiscal year 1983.[35] Funding beyond fiscal year 1983 is uncertain.

---

[32] Ibid., p. 4.

[33] U.S. National Aeronautics and Space Administration. Lyndon B. Johnson Space Center. AgRISTARS annual report—fiscal year 1981. Houston, Tex., NASA, January 1982.

[34] Jim Smith, National Oceanic and Atmospheric Administration, private communication, June 1982.

[35] Richard McArdle, U.S. Department of Agriculture, private communication, June 1982.

TABLE 5-4

NASA FUNDING HISTORY FOR THE AGRISTARS PROGRAM*
(in $ millions)

Fiscal Year	FY80 Budget Request	FY81 Budget Request	FY82 Carter Budget Request	FY82 Reagan Revised Request
FY80	16.0	16.0	16.0	16.0
FY81	28.0	33.2	31.4	21.4
FY82	32.3	38.4	33.1	23.1
FY83	34.2	40.9	33.6	23.6
FY84	35.1	40.9	36.9	26.9
FY85	11.4	14.0	29.4	19.4
FY86			15.9	5.9
FY87			8.7	8.7
TOTAL..........	156.9	183.4	205.0	145.0

---

* Figures provided by NASA, June 3, 1981.

c. Geological applications program.—Landsat data can be used in a wide variety of geological applications, such as mineral and energy resource exploration (including oil, uranium, and geothermal energy), nuclear plant siting and waste disposal, charting glaciers and shallow seas, and geological mapping in general.[36] Data from other satellites, such as Seasat (chapter 6) and the Heat Capacity Mapping Mission (section II) are also used for geological purposes. As with other Landsat applications, the satellite data augments rather than replaces conventional techniques.

For example, by studying features on Landsat photographs, scientists can detect and map various rock formations that reveal areas of mineral deposits. Photographs of Kentucky and Tennessee led mining company representatives to at least seven promising areas of lead and zinc deposits which were more than 1,500 feet (457 meters) deep. The Landsat photographs had shown circular features, caused by color variations in vegetation growing above the rocks, which could not be discerned from the ground. The color variations were caused by ions from mineralized areas of subsurface rock (which were circular) migrating vertically and getting into the soil and water above, and eventually into the vegetation. The leaves would change color, and these variations were picked up by Landsat.[37]

---

[36] See for example: Alexander F. H. Goetz and Lawrence C. Rowan. "Geologic Remote Sensing." Science, Feb. 20, 1981, pp. 781-791; Floyd F. Sabins, Jr. "Remote Sensing: Principles and Interpretation." San Francisco, W. H. Freeman & Co., 1978.

In January 1981, NASA proposed a geological applications program [GAP] as part of its fiscal year 1982 budget request. The program was designed to assess the ability of Landsat and other remote sensing systems to discover oil and minerals, and was to have run for 5 years. Total cost of the program was estimated at $105 million; funding in fiscal year 1982 was to have been $10 million. The Reagan administration eliminated the program in its revised request to Congress in March 1982. The House Science and Technology Committee restored the $10 million when it reported out the NASA authorization bill for that year, stating that "The committee believes that the importance of applying NASA's unique expertise in cooperation with private enterprise and other Federal agencies to improve the effectiveness of global assessment, exploration, and development of strategic minerals and energy sources through the use of space techniques supports initiation of this activity in fiscal year 1982." [38]

The Senate Commerce, Science, and Technology Committee did not recommend funding the program, nor did either of the appropriations committees, so the program has been terminated.

D. Making the Landsat Program Operational

1. Summary

The major domestic issue which has enveloped the Landsat program since the beginning is how and when to "go operational" with the system, that is, to transition from research and development into an operational mode. The definition of the term "operation" has in itself been troublesome for the past several years, for although Landsat data has been used in an operational sense for a long time, it was felt that the technology and the system itself were still experimental. Thus it retained its funding and authorization status as an R&D program long past the time when many users felt that it was functioning operationally.

Another problem has been deciding whether the program should be transferred out of the Government and into the private sector or whether the Government should operate the space segment (the satellites and associated ground systems for command and control), with the private sector taking over the ground segment (data acquisition, processing, archival functions, and dissemination).

The formal acknowledgement of Landsat as an operational system, together with a commitment to program and data continuity, are needed as a wide user base for the data. Users are concerned that they might invest thousands of dollars in equipment and training for utilization of Landsat data, only to have the R&D program terminated.

---

[37] "Satellites Spot Minerals More Than 1,500 Feet Deep." Dallas Morning News, Mar. 13, 1978.

[38] U.S. Congress. House. Committee on Science and Technology. Authorizing appropriations to the National Aeronautics and Space Administration for fiscal year 1982; report to accompany H.R. 1257. Report No. 97-32. May 8, 1981. Washington, U.S. Government Printing Office, 1981. p. 12.

NASA's mandate is to perform research and development, not operate programs, so NASA's role was expected to phase out (except for advanced R&D) once the technical viability of the system and the utility of the data had been proven, just as the agency phased out of the weather satellite program.

The Executive Branch conducted several studies on issues involved in making the remote sensing satellite system operational. During the Carter administration, three directives were issued which impacted the program is some way; the last of these (PD-54) transferred operational authority for the program from NASA to NOAA, although eventual transfer to the private sector was envisioned. The administration hoped that this action would ease concerns about program continuity.

When President Reagan took office, however, the emphasis shifted to transferring operations to the private sector as soon as possible. NOAA announced that the launching of remote sensing satellites past Landsat D' would "depend on the private sector," once again calling into question the continuity of the program.

As 1981 ended, NOAA was preparing to take over operational responsibility for the Landsat program as of January 31, 1983 (six months after the launch of Landsat D), and the Cabinet Council on Commerce and Trade was deliberating on what the best method of transferring the Landsat program to the private sector would be, and whether meteorological satellite should also be transferred to the private sector for management and operation.

2. Early options

Prior to NOAA being selected as the manager of the operational Landsat system, several other Government agencies had been considered as a possible home for the operational program, including NASA (with a change in its organic act to provide for operating the program), the Department of Agriculture, and the Department of Interior. Another potential alternative was to create a new government agency either to operate just an earth resources satellite system or a larger agency (such as a Department of Natural Resources) which could incorporate other functions as well.

Legislative options for making the program operational have been debated for many years. The first bill to address the issue was introduced in 1973, one year after the launch of the first satellite, and it has been debated in every Congress since that time. The various bills are described in section 2; none has been reported from committee, however.

3. President Carter's Directives: Transferring Landsat to NOAA

During the Carter Administration, three major space policy directives were issued, each of which addressed the civil land remote sensing system in some respect. The first, PD-37, dealt with the relationship between the military and civil space programs; the second, PD-42, concerned goals for the civil space program; and the third, PD-54, transferred responsibility for Landsat from NASA to NOAA.

a. PD-37 and PD-42.—The full texts of these two presidential directives are classified, but the White House released unclassified fact sheets outlining their major points, from which the following is excerpted.

The fact sheet on the first directive, PD-37, was released on June 19, 1978. Provisions of the policy directive relating to satellite remote sensing included the following:

> The United States will develop and operate on a global basis active and passive remote sensing operations in support of national objectives.
>
> The United States will encourage domestic commercial exploitation of space capabilities and systems for economic benefit and to promote the technological position of the United States; however, all United States Earth-oriented remote sensing satellites will require United States Government authorization and supervision or regulation.
>
> Advances in earth imaging from space will be permitted under controls and when such needs are justified and assessed in relation to civil benefits, national security, and foreign policy. Controls, as appropriate, on other forms of remote earth sensing will be established.
>
> Data and results from the civil space program will be provided the widest practical dissemination to improve the condition of human beings on earth and to provide improved space services for the United States and other nations of the world.[39]

Thus, the directive encouraged private sector interest in remote sensing satellites, while reserving the Government's right to supervise such activities. In addition, PD-37 set forth conditions under which the image resolution of remote sensing satellites could be improved, that is, "when such needs are justified and assessed in relation to civil benefits, national security, and foreign policy".

The directive also established a Policy Review Committee [Space] within the National Security Council which was immediately directed to conduct a study assessing the needs and aspirations of the civil space program.

The results of that study became the second Carter space policy directive, PD-42. The White House issued a fact sheet on PD-42 on October 11, 1978, stating, inter alia, that the President had reached the following decisions regarding remote sensing:

> *Remote Sensing Systems.*—Since 1972 the United States has conducted experimental civil remote sensing through Landsat satellites. There are many successful applications and users, including Federal departments, other nations, a number of states, and a growing number of commercial organizations. The United States will continue to provide data from the developmental Landsat program for all classes of users. Operational uses of data from the experimental system will continue to be made by public, private, and international users. Specific details and configurations of the Landsat system and its management and organizational factors will evolve over the next several years to arrive at the appropriate technology mix, test or-

---

[39] Office of the White House Press Secretary. Fact sheet. June 19, 1978.

ganizational arrangements, and develop the potential to involve the private sector.

Integrated Remote Sensing System.—A comprehensive plan covering expected technical, programmatic, private sector, and institutional arrangements for remote sensing will be explored. NASA will chair an interagency task force to examine options for integrating current and future systems into an integrated national system. Emphasis will be placed on defining and meeting user requirements. This task force will complete its review prior to the fiscal year 1981 budget cycle.

The Private Sector.—Along with other appropriate agencies, NASA and Commerce will prepare a plan of action on how to encourage private investment and direct participation in civil remote sensing systems. NASA and Commerce will be the contacts for the private sector on this matter and will analyze proposals received before submitting them to the Policy Review Committee [Space] for consideration and action.[40]

b. PD-54—Designating NOAA to Manage the Landsat System.—Following the completion of the PD-42 study, the administration turned its attention to dealing specifically with the issue of making the remote sensing program operational.

In November 1979, the Carter administration announced its decision to assign responsibility for an operational civil remote sensing spacecraft system to NOAA, including management of all U.S. land, sea, and weather applications satellites and associated ground systems. The major elements of the policy, set forth in PD-54, were as follows:

> The formal establishment of an operational remote sensing system would commit the Federal Government to the development and maintenance of long-term systems, rather than a series of experimental missions, and should provide the user community with the assurance needed to invest the necessary funds for equipment and personnel training.
>
> The administration would request fiscal year 1981 funding for NOAA to study ways to further private sector opportunities in civil land remote sensing activities, through joint ventures with industry, a quasi-governmental corporation, leasing, and so forth, with the goal of eventual operation of these activities by the private sector.
>
> In an effort to make certain that user needs were represented to NOAA, the Department of Commerce would establish and chair a program board for continuing Federal coordination and regulation of civil remote sensing activities. The involved Federal organizations (such as the Departments of Defense, Interior, Agriculture, State, Transportation, and Energy, CIA, NASA, AID, and EPA) would be represented. The National Governors' Association and the National Conference of State Legislatures would be invited to participate.
>
> Separate management of civilian and military programs would continue. However, joint civilian/military activities

---

[40] Office of the White House Press Secretary. U.S. Civil Space Policy. Fact sheet. Oct. 11, 1978. p. 2.

would be pursued where both parties' objectives could best be met through this approach.

Users, who were then paying only for the costs of data reproduction, would have to bear a much greater share of the operational system costs. These costs would increase for both foreign and domestic users.

Recognizing that new remote sensing space spacecraft were under development in other countries, the administration would contact these nations to find the best way to guarantee complementary systems.

NASA would remain responsible for spacecraft research and development.[41]

NOAA was chosen as the lead agency for a variety of reasons. An important factor was that NOAA's National Environmental Satellite Service has managed the operational weather satellite program for over 10 years, unlike other contender agencies with no satellite programs. Also, consideration was given to the cost savings of a single agency approach. If the Department of Interior or the Department of Agriculture had been given responsibility for Landsat, and weather and ocean spacecraft systems remained in NOAA, Federal responsibilities in the overall management of remote sensing satellites would have been split, thereby increasing costs. Finally, NOAA, unlike the Departments of Interior or Agriculture, had no Landsat programs which could conceivably prejudice its design of future spacecraft systems to serve in-house needs at the expense of other user needs.

The recommendation of the Space Policy Review Committee was not unanimous. Among those who approved of NOAA as the lead agency were NASA and the Department of Agriculture, the prime user of Landsat data. The Deprtment of Interior and AID maintained that the Department of Interior should have been given management responsibility because of its extensive experience in data processing and distribution.

c. Implementation of PD-54.—Though the Carter administration had outlined the concept for the operational remote sensing satellite system and called for the program's transfer to NOAA, there were a number of issues which awaited further definition. A plan for the transition of management from NASA to NOAA had to be prepared, and technical requirements for an operational system had to be established. Among the questions to be resolved were: the number of satellites needed to provide useful, repetitive coverage with appropriate provisions for backup satellites in the event of equipment failure, the rapidity with which useful data products could be made available to users, the usefulness of data format, and the manner in which technical innovations would be introducted into the system.

At hearings in the summer of 1980, NOAA submitted a discussion document to Congress entitled "Planning for a Civil Operational Land Remote Sensing Satellite System: A Discussion of Issues and Options." [42] The document contained some policy and technical options related to implementing an operational system, but noted that decisions on these options would probably await the fiscal year 1982 budget deliberations, and that decisions on the design and funding of a fully operational program were reached, the Federal Government would depend on the NASA-planned Landsat D system.

---

[41] Office of the White House Press Secretary. Fact sheet. Nov. 20, 1979.

[42] U.S. Department of Commerce. National Oceanic and Atmospheric Administration. "Planning for a Civil Operational Land Remote Sensing Satellite System: A Discussion of Issues and Options." Rockville, Md., NOAA, June 20, 1980. 130 pp.

The NOAA plan envisioned a two phase program for transferring land remote sensing satellites into the private sector. During the first phase, the program would be based on Landsat D and any required follow-on satellites, to insure continuity of data.

Under this scenario, NOAA will assume responsibility for Landsat's space segment on January 31, 1983, 6 months after Landsat D is launched. Initially, NOAA will only have responsibility for the Landsat D multispectral scanner, since the thematic mapper is still experimental. NASA will retain responsibility for the thematic mapper for approximately 18 months, after which NOAA will assume responsibility for that instrument as well. Responsibility for data archiving and distribution at the EROS data center will be transferred to NOAA during 1983-84; the Department of the Interior will retain responsibility for research related to Landsat applications and conducting training program for utilizing Landsat data, since these functions primarily service the missions, of the Department of Interior. As noted earlier, NOAA has indicated that costs for Landsat data will rise as of October 1, 1982, in keeping with the provisions of PD-54 regarding users paying more for their share of the operational system.

NOAA estimated that the second phase of the program, a fully operational system based on advanced technology (multinear arrays) and designed to meet user needs, could not be ready before 1989. The plan anticipates private sector operation of the fully operational system, and NOAA outlined several institutional alternatives for achieving this goal.

NOAA indicated in this document that it felt it did not have the requisite authority to conduct the Landsat program. Such language is expected to be included in fiscal year 1983 funding legislation.

NOAA has announced plans to establish a Land Remote Sensing Satellite Advisory Panel to advise NOAA on how to manage the Landsat program. Its members are expected to come from industry, State government, and the academic community.

4. Congressional efforts to establish an operational Landsat system

Legislation was first introduced in Congress to establish an operational Landsat system in 1973, one year after the launch of Landsat 1 (then called the Earth Resources Technology Satellite 1 [ERTS 1]). Between 1973 and 1981, nine bills dealing specifically with the operational Landsat question (all in the Senate) and six other bills dealing more generally with U.S. space policy and including reference to remote sensing issues (in the House and Senate), have been introduced. None has been reported from committee.

a. 93d Congress (1973-74).—Two bills were introduced in the 93d Congress providing for institutional arrangements for an operational Landsat system. The first, S. 2350, was introduced by Senator Frank Moss, then chairman of the Senate Committee on Aeronautical and Space Sciences [43] on August 3, 1973. The second, S. 3484, was introduced by Senator James Abourezk on May 13, 1974.

Hearings on both bills were held by the Senate Committee on Aeronautical and Space Sciences in August and September 1974.[44] The organizations established by both bills would have been responsible for the operation of an Earth Resources Observation System, and for determining improved means of data acquisition and interpretation. Both bills provided that NASA would design, develop, and operate the space segments of the respective earth resources satellite systems.

The major difference between the bills was that S. 2350 designated NASA as the lead agency for the system, while S. 3484 assigned that responsibility to the Department of Interior. The bills seemed to reflect different philosophies; in assigning the lead role to NASA, S. 2350 emphasized the technical aspects of the Landsat program, while S. 3484 focussed on the needs of the user community.

The Moss bill (S. 2350), would have required NASA to establish an Office of Earth Resources Survey Systems with primary responsibility for transforming remote sensing technology into an operational reality. Thus, in addition to its existing responsibility for launching the satellite, controlling the satellite, and receiving satellite data, NASA would also have had responsibility for data dissemination.

At the hearings, a major criticism of the bill was its artifical segregation of Earth resources activities from closely related satellite applications programs within NASA such as meteorology and oceanography. In establishing a separate office within NASA, it was argued that the legislation would unduly reduce NASA's flexibility to organize itself most effectively to carry out its functions.

The bill also elicited unfavorable comments for assigning NASA the responsibility and authority for data interpretation and dissemination. The criticism was that these functions would be more appropriately left to the users and user agencies which are, by virtue of applications experience in their respective disciplinary fields, more competent to meet user requirements. Several experts felt that NASA's responsiveness to user requirements could be assured by other, more effective methods such as increased interaction between NASA and the user community.

Concern was also expressed that if the Landsat system were to be declared operational, NASA would be unable to secure the appropriate radio frequencies. Critics of the bill pointed to the assignment of three operational frequencies to the Department of the Interior for an Earth Resources Observation System by the Office of Telecommunications Policy.[45] However, according to Dr. James

---

[43] This committee was abolished at the beginning of the 96th Congress and its functions were transferred to the Senate Commerce, Science, and Transportation Committee.

[44] U.S. Congress. Senate. Committee on Aeronautical and Space Sciences. Earth Resources Satellites. Hearings, 93d Congress, 2d session. Aug. 6, 8, 9 and Sept. 18, 1974. Washington, U.S. Government Printing Office, 1974.

[45] The Office of Telecommunications Policy was subsequently abolished and many of its functions were transferred to the National Telecommunications and Information Agency in the Department of Commerce.

Fletcher, then NASA's Administrator, "Frequencies are assigned to functions or services, not agencies. Therefore, frequency allocations do not impact the policy on which agency should manage the space segment of a future operational system." [46]

The Abourezk bill (S. 3484) would have established an Earth Resources Observation Administration within the Department of Interior. Like the Moss bill, S. 3484 was attacked because it excluded related systems such as meteorological satellites from its definition of earth resources satellite systems. The limitation of NASA's R&D in Earth resources to activities supported and funded by the Department of Interior was thought to be a peculiar compartmentalization of the space effort which would unnecessarily complicate the total space program and thereby be contrary to the National Aeronautics and Space Act of 1958. In addition, some witnesses commented on the inappropriateness of having the Department of Interior, with no overall technical systems design experience, direct NASA's R&D efforts.

Both bills omitted provisions concerning the role of the private sector and allocation of costs and reimbursements for services.

In general, the consensus seemed to be that the interests of a successful Landsat program would best be served by assigning to NASA the responsibility, authority, and resources for the research, development, and operation of the Earth Resources Satellite System to the point of delivering to user agencies a standard digital tape product; and that the authority, responsibility, and resources for primary data archiving and dissemination, for standard processing (digital and photographic), and research and development in image interpretation should reside with the user agencies (which was essentially a description of the existing arrangement).

b. 94th Congress (1975-76).—Following the aforementioned hearings, it was determined that Landsat was not ready to become an operational program, and a new bill, S. 156, was introduced in the first session of the 94th Congress to provide for continuation of Landsat in an experimental mode. The provisions of S. 156 were later incorporated into NASA's fiscal year 1976 authorization bill (H.R. 4700).

(1) S. 3759.—In the second session of the 94th Congress, Senator Moss introduced another bill for establishing an operational earth resources satellite system (S. 3759, August 24, 1976). The bill incorporated a goal increasingly applied to space applications programs—the evolution to self sufficiency. The bill was based on a report prepared for the committee by Charles Mathews, who had formerly served as NASA's associate administrator for applications.[47]

The legislation would have established a mechanism whereby private industry would be encouraged to assume an increasingly larger role in the support of remote sensing technology. Simultaneously, some Government involvement would have been retained to support R&D on advanced systems and to provide safeguards to preserve the system's integrity and to provide reassurance to foreign nations that might be apprehensive about the commercialization of worldwide satellite imagery.

---

[46] Earth resources satellites hearings, op. cit., p. 186.

[47] U.S. Congress. Senate. Committee on Aeronautical and Space Sciences. "An Analysis of the Future Landsat Effort." Committee Print. 94th Congress, 2d session. Washington, U.S. Government Printing Office, 1976. 38 pp.

Specifically, the bill would have established an Office of Earth Resources Policy in the Executive Office of the President under a Director appointed by the President subject to Senate confirmation. The new presidential office would have formulated requirements for a private earth resources corporation, and together with the corporation, would have operated the Global Resources Information System. Initially, the corporation would have functioned only as an information distribution organization, but eventually would have assumed all Landsat activities except spacecraft research and development. Spacecraft development would have remained with NASA.

This move of the experimental Landsat program to a fully operational system would have been accomplished in three phases under the terms of the bill. Phase I was intended as a validation phase, encompassing the period from when the bill was passed to approximately 1985. Institutional and system arrangements would have been formulated during this period, with the Office of Earth Resources Policy having responsibility for overall guidance. During this phase, NASA would have retained responsibility for managing the orbiting spacecraft, while the Department of Interior's EROS data center would have continued its functions related to Landsat data and image processing. The corporation would have been responsible for data dissemination, and private industries would have been invited to increase their participation in the Landsat program.

In phase 2, the corporation would have taken control of every element of the system, including management of the spacecraft and central processing of the data and imagery. At this stage, an increasing number of private industries were expected to become involved in various aspects of the program.

Phase 3 operations would have begun in 1990. At this point, it was expected that the system would be nearly self-sufficient, and many industrial firms would be involved, with a high degree of business competition for the same services. The bill assumed that by this time, the user market would have solidified and increased substantially. Industry was expected to sponsor R&D with its own resources.

No action was taken on the bill.

(2) 1976 GAO report.—On January 30, 1976, the General Accounting Office (GAO) released its first report on Landsat.[48] The report was prepared at the request of the chairman of the Subcommittee on HUD-Independent Agencies of the Senate Appropriations Committee, and was intended to provide general information to assist the Congress in exercising its legislative and review functions.

The report concluded, inter alia, that there should be a long-range plan which includes user requirements "so that it can be determined when the state of the art provides the users with an adequate capability for determining success or failure of the Landsat project." GAO recommended that NASA initiate development of a plan including requirements, milestones, and dates for evaluating progress in determining when and if the program should become operational. Specifically, GAO stated that such a plan address "(1) the assignments of roles and responsibilites to the involved [Government] agencies, (2) interrelationships among oceanographic, meteorological, and earth resources satellite systems, (3) alternative organizational arrangements for operational systems reflecting differing degrees of Government, private sector, and international participation, and (4) estimated resource and funds requirements to be filled by the Federal Government.[49]

---

[48] U.S. General Accounting Office. Land satellite project; study by the staff of the U.S. General Accounting Office. Washington, GAO, Jan. 30, 1976. 42 pp. PSAD-76-74.

c. 95th Congress (1977-78).—During the 95th Congress, three bills were introduced in the Senate regarding an operational Landsat system and hearings were held, but none was reported from committee. No House bill was introduced, but hearings were held and a committee print listing findings and recommendations was issued. Two bills dealing in general terms with space policy, including remote sensing, were introduced in the Senate, but no action was taken on either measure. The General Accounting Office (GAO) released two studies on Landsat, in 1977 and 1978 respectively.

(1) S. 657.—On February 7, 1977, a bill to establish an Earth Resources and Environmental Information System was introduced by Senator Wendell Ford (S. 657).

Under the terms of this bill, NASA would have been designated manager of the space segment—the satellites and associated ground equipment for command and control of the satellites. The Secretary of Interior would have been designated as the manager of the data handling segment, that portion of the system that receives data from the satellites, processes the data, and disseminates the resulting products to users.

The bill would have required the Secretary of Interior to furnish the system data and information to Government and private users, domestic and foreign, on an equal basis. In addition, the Department of Interior would establish regional distribution centers in the United States to provide ready access to the information. The Director of the Office of Science and Technology Policy (OSTP) in the Executive Office of the President would have coordinated and overseen the development, validation, and operation of the system.

According to the provisions of the bill, NASA would have been given 7 years to establish an operational space segment, but would have permanently retained responsibility for all R&D related to the system.

Hearings were held on S. 657 in May and June, 1977.[50] One major criticism of the bill was its omission of the Department of State in its arrangements for data dissemination programs for foreign nations. Testimony from the OSTP presented the administration's view that Landsat technology was not yet ready to form the basis of an operational system. No further action was taken on the measure.

---

[49] Ibid., pp. 39-20.

[50] U.S. Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Science, Technology, and Space. Earth Resources and Environmental Information System Act of 1977. Hearings, 95th Congress, 1st session, May 24, 25, June 13 and 14, 1977. Washington, U.S. Government Printing Office, 1977. 352 pp.

(2) 1977 GAO report.—The General Accounting Office released its second study of the Landsat program shortly before the hearings.[51] GAO noted that in response to a recommendation made in its first report, NASA had begun to develop a plan for evaluating progress toward the goal of deciding if and when to make the Landsat program operational, but that no agreement had been reached among the users of what performance objectives had to be achieved in the 1981-86 time period to justify an operational system.

GAO concluded that it was premature to make Landsat operational, and suggested that a study be prepared to assess the benefits to be gained versus the expenses and resources required to establish the system. The agency also concluded that a clear statement of Government policy was required regarding support of an operational Landsat system, including consideration of technical, political, economic, institutional, and international issues. GAO recommended that OSTP, in conjunction with NASA and other cognizant Federal agencies, study the issues involved and recommend a Government policy role in satellite remote sensing.

(3) 1977 House Science and Technology Committee Hearings.—Although no specific legislation related to establishing an operational earth resources satellite system had been introduced in the House, the House Science and Technology Committee's Subcommittee on Space Science and Applications held hearings on this general topic in June 1977.[52]

Charles Mathews, who had prepared a report for the Senate committee in 1976, prepared two additional reports for the House committee in 1977, which served as the basis for the hearings. The first dealt with defining an earth resources information system, while the second addressed institutional arrangements required for transitioning from an experimental to an operational system.

In the latter paper, Mathews concluded that NASA should be responsibile for the space segment, while noting that this should not preclude commercial ventures of an ancillary nature, and that the Department of Interior's EROS data center should operate a centralized data handling segment. Information extraction and interpretative services were already highly decentralized, according to Mathews, and open to all sectors involved with earth resources satellite services. Mathews also commented that NASA and the EROS program should sponsor application demonstrations in close cooperation with users. Testimony was received from a wide variety of witnesses, including Government and the private sector.

In November 1977, a committee print was released based on the hearings which listed 25 findings and 10 recommendations. The recommendations were as follows:

> The executive branch should provide a mechanism to assure the participation of all elements of the user community in all phases of development of an earth resources information system.

---

[51] U.S. General Accounting Office. "Landsat's Role in an Earth Resources Information System;" report to the Congress by the Comptroller General of the United States. Washington, GAO, June 10, 1977. 37 pp. PSAD-77-58.

[52] U.S. House. Committee on Science and Technology. Subcommittee on Space Science and Applications. Earth Resources Information System. Hearings. 95th Congress, 1st session, June 21, 22, 23, 1977. Washington, U.S. Government Printing Office, 1977. 672 pp.

Within the next 12 months the Federal Government should commit to a 5-year earth resources information system validation program with a stated goal of an orderly transition to an operational system at the end of the validation program.

Within the next 18 months, the Office of Science and Technology Policy should report to the Congress a specific program plan for accomplishing the earth resources information system validation program.

The exectutive branch should study the various institutional alternatives, establish the criteria from which to choose an institutional alternative, and recommend to the Congress the preferred institutional alternative for an earth resources information system. Prior to such recommendation, no promising institutional alternative should be foreclosed.

The executive branch should study and recommend to the Congress a pricing policy which encouraged competitive ground operations and encourages market development.

The executive branch should study and recommend to the Congress an approach that would enable transition of the data handling and data dissemination activities to the private sector.

The Federal Government should provide a clear understanding as to what are the Government's roles and what are the private sector roles with a clear commitment of the Government to the functions for which it is responsible.

The United States should continue to provide and encourage the development of expertise in foreign countries and provide for open access to the data from an earth resources information system.

The executive branch should clarify the roles of the Federal agencies by designating a lead agency and assigning responsibilities.

Within the next 12 months, the executive branch should establish a working board of participating members with a designated lead agency serving as chairman. The Office of Science and Technology Policy should submit to the Congress an organization plan for establishing such a working board.[53]

(4) 1978 GAO report.—In April 1978, GAO released the third in its series of reports on the Landsat program.[54] GAO noted that the OSTP was considering some technical and funding issues related to Landsat D and was planning to create a Cabinet level policy group to study broader issues regarding an operational remote sensing satellite system. The report recommended that the Director of OSTP periodically inform NASA as to the status of these activities.

(5) S. 3589.—Introduced by Senator Stevenson on October 12, 1978, the Earth Data and Information Service Act of 1978 would have established an Earth Data and Information Service as a separate office within NASA to manage the spacecraft, ground systems, and data processing segments of an operational remote sensing sat-

---

[53] U.S. Congress. House. Committee on Science and Technology. Subcommittee on Space Science and Applications. Earth Resources Information Systems. Committee Print. 95th Congress, 1st session. November 1977. Washington, U.S. Govt. Print. Off., 1977. pp. 1-5.

[54] U.S. General Accounting Office. "Landsat Policy Issues Still Unresolved;" report to the Congress by the Comptroller General. Washington, GAO, Apr. 17, 1978. PSAD-78-58. 27 pp.

ellite system. The Administrator of NASA would have been given authority to establish and manage the Service, while direct operational responsibility would have rested with the General Manager of the Service, who was to be appointed by the President by and with the advice and consent of the Senate. Although the Service was to be separated from NASA's research and development function, a principle reason for choosing NASA for this assignment was the importance of maintaining close ties between operational management of the systems and continuing research and development activities.

The Service would have been directed to meet user needs at terms to be established by the Administrator. Income eventually would have covered the costs of maintaining and operating the Service.

An interim period of 7 years was to be used for developing the institutional, financial, technical, and marketing capabilities needed to bring the Service to full operational status. During this interim period, the President would have been directed to prepare and transmit to the Congress recommendations on the appropriate organizational entity to continue an operational service after the interim period.

There was no action on this measure. The bill was reintroduced in the 96th Congress as S. 663.

(6) S. 3625.—Senator Schmitt introduced S. 3625 on October 14, 1978. Entitled the Earth Resources Information Satellite Act, the bill would have established a policy to create a commercial earth resources satellite corporation which was to be made operational as soon as possible and provide the widest possible participation by private industry, on a nondiscriminatory basis.

The bill would have created the Earth Resources Information Satellite Corporation, controlled by a 17-member Board of Directors. Three of the members would have been appointed by the President; the Departments of Agriculture, Commerce, and Interior, and the National Association of State Governors were each to appoint one member; and 10 were to be elected by the stockholders. The corporation was authorized to issue stocks carrying voting rights; wide distribution to the American public would have been encouraged.

The corporation would have had authority to market raw and preprocessed data on earth resources, and to own and operate the earth resources satellites, ground receiving stations, and information distribution centers for the provision of raw and preprocessed data. The corporation would have been regulated by the Federal Communications Commission, which was charged with insuring effective competition by, among other things, consulting with the Small Business Administration to insure that equitable opportunities were provided for small businesses and to insure that the opportunity to purchase earth resources data, under just prices, would be available to all persons and organizations.

The bill would have had NASA furnish launch services to the corporation on a reimbursable basis, conduct research and development to refine the capabilities of the system, and coordinate activities of the various governmental agencies that were involved with or benefited from the corporation.

There was no action on this measure. The bill was reintroduced in the 96th Congress as S. 875.

(7) Space policy legislation: S. 3530 and S. 3599.—At the end of the 95th Congress, following the release of President Carter's directive on civilian space programs [PD-42], Senators Stevenson and Schmitt introduced bills providing alternatives to the President's space policy. Because the bills were introduced so late in the session, their primary purpose was seen as serving as a discussion point, from which future legislation might be introduced. In fact, both bills were revised and reintroduced in the 96th Congress.

Since specific legislation had been introduced already concerning operational remote sensing satellites systems, these bills dealt with the issue only peripherally. The Stevenson bill, S. 3530, concerned the next 10 years in space, and emphasized the role of the private sector. Among the provisions of the bill was the goal of establishing and operating a system of remote sensing of the Earth's resources, environment and related conditions. The Schmitt bill, S. 3599, took a longer view of space activities and covered the next 30 years in space. One goal included in the bill was to establish a World Information System by the year 1990 which would have included an operational earth resources monitoring system for collecting and making available data necessary for maximum efficiency and environmentally sound utilization of natural and agricultural resources on Earth.

No action was taken on either measure.

d. 96th Congress (1979-80).—During the 96th Congress, three Senate bills dealing specifically with an operational remote sensing satellite system were introduced and hearings were held on two of the measures. Although there was no similar House bill, hearings were held by the Science and Technology Committee.

In addition, two Senate bills and two House bills were introduced dealing more generally with the subject of space policy which included references to remote sensing from space. Hearings were held on the Senate space policy bills, and the House held hearings on space policy although they did not directly relate to the legislation that had been introduced.

(1) Space policy legislation: S. 212 and S. 244.—Senators Schmitt and Stevenson reintroduced their space policy bills from the 95th Congress soon after the 96th Congress convened. The Schmitt bill, S. 212 (January 24, 1979) was a substantial revision of the earlier measure, although the sections related to remote sensing remained relatively the same. S. 212 declared that it was in the national interest to establish a U.S. space policy directed toward creation of a world information system during the 1980's that could consist of "permanent, generally self-financing services in telecommunications, weather and ocean forecasting, [and] Earth resources sensing." In addition, the new measure included language from the previous version of the bill regarding establishment of a World Information System.

The new Stevenson bill, S. 244 (January 29, 1979) included generally the same provisions related to remote sensing as had been in the earlier version.

Hearings were held on the bills on January 25, 31 and February 1, 1979, but no further action was taken.[55]

(2) 1979 House Science and Technology Committee hearings on space policy.—Although no space policy legislation had been introduced in the House at the time, the Committee on Science and Technology held one day of hearings on civilian space policy in February 1979. The hearings addressed space policy in general, not specifically the issue of remote sensing.[56]

(3) S. 663 and S. 875.—Introduced by Senator Stevenson, S. 663 (March 13, 1979) was essentially identical to S. 3589 which had been introduced in the 95th Congress. Similarly, S. 875 (April 4, 1979) introduced by Senator Schmitt, was virtually identical to S. 3625 from the 95th Congress, with one notable exception. The earlier bill would have required the Earth Resources Satellite Corporation to be made operational "as soon as possible," while the new bill stated that it be made operational no later than 2 years after the enactment of the bill.

Hearings were held on these two bills in April and July 1979.[57] Testimony was received from a variety of Government and private sector individuals, many of them users of Landsat data. The administration position was presented by Dr. Frank Press, Director of OSTP. Press reminded the committee that President Carter had asked NASA to chair an interagency task group to examine options for integrating current and future potential systems, including technical, programmatic, and institutional arrangements. In addition, Carter had directed NASA and the Department of Commerce to actively explore private sector interest, roles and conditions of Government control vis-a-vis an operational remote sensing system. Press expressed the administration's position that the executive and legislative branches were on a convergence path (i.e., that the proposed legislation was similar to what the administration was doing already), and legislation was therefore not needed at that time.

No further action was taken on either bill.

(4) 1979 and 1980 House Science and Technology Committee hearings on operational civil remote sensing systems.—The House Science and Technology Committee held two sets of hearings on the topic of operational remote sensing systems during the 96th Congress although there was no legislation introduced in the House to accompany the hearings. The first set was held in May 1979, prior to President Carter's designation of NOAA to take over the Landsat program, and the second was held in June and July 1980 after that action had been taken.

---

[55] U.S. Congress. Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Science, Technology, and Space. "U.S. Civilian Space Policy." Hearings. 96th Congress, 1st session, Jan. 25, 31, and Feb. 1, 1979. Washington, U.S. Government Printing Office, 1979. 423 pp.

[56] U.S. Congress. House. Committee on Science and Technology. "Oversight: President's Civilian Space Policy." Hearing. 96th Congress, 1st session, Feb. 14, 1979. Washington, U.S. Government Printing Office, 1979. 66 pp.

[57] U.S. Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Science, Technology, and Space. "Operational Remote Sensing Legislation" (Parts 1 and 2). Hearings. 96th Congress, 1st session. Part 1: April 9 and 11, 1979. Part 2: July 31, 1979. Washington, U.S. Government Printing Office, 1979.

The 1979 hearings[58] were held to examine whether or not the executive branch had implemented any of the committee's recommendations made in November 1977. At the hearings, John McLucas, representing Comsat, stated that his organization was prepared to invest considerable resources in earth remote sensing technology and to assume reasonable risks in making the program commercially successful. McLucas outlined a plan envisioned by Comsat to transition land remote sensing from the Government into the private sector in which NASA would continue to operate the program for an interim period of time while Comsat, working with NASA, would define a system for the future based upon user requirements.

In the long run, NASA would continue to perform R&D for advanced technology, but the private sector would operate the system. McLucas stressed that the Government would be expected to purchase its land remote sensing data from the private sector operators, and not launch its own competitive system. In addition, the Government would be expected to guarantee a minimum amount of services and data that it would procure each year. McLucas estimated that the Government would have to make a commitment to purchase between 65 and 75 percent of the revenue requirements of the system.

Administration witnesses testified that studies were ongoing within the executive branch on how to make the Landsat system operational.

In the summer of 1980, the committee again held hearings, this time to examine plans for the transition of the Landsat program from NASA to NOAA.[59] Congress had been awaiting the plan for the NOAA transition since the President's announcement of the transfer in November 1979. NOAA submitted a policy document outlining the issues involved in such a transition shortly before the hearings ("Planning for a Civil Operational Land Remote Sensing Satellite System: A Discussion of Issues and Options," cited previously).

The first 2 days of hearings focused on the role of the private sector in the operational remote sensing system. Witnesses from the private sector agreed that a larger private sector role in the program was desirable, but disagreed on whether that meant the entire system should be operated outside the Government, or only the ground segment.

Following up on its testimony from the previous year, a Comsat representative, John Johnson, testified that his company had recommended that NOAA define the Government's needs for land remote sensing data and determine the cost of establishing a Government owned system to meet those needs and make that data available to the private sector so that interested companies could then make a proposal to provide those services, presumably at a lower cost.

---

[58] U.S. Congress. House. Committee on Science and Technology. Subcommittee on Space Science and Applications. Earth Resources Data and Information Service. Hearings. 96th Congress, 1st session, May 2 and 3, 1979. Washington, U.S. Government Printing Office, 1979. 219 pp.

[59] U.S. Congress. House. Committee on Science and Technology. Subcommittee on Space Science and Applications and Subcommittee on Natural Resources and Environment. Hearings. 96th Congress, 2d session, June 24, 25, and July 29, 1980. Washington, U.S. Government Printing Office, 1980. 315 pp.

The third day of hearings, a month later, took testimony from the executive branch. Speaking on behalf of NOAA, Richard Frank noted that in the time since the announcement of NOAA as the operational agency for Landsat, the agency had begun extensive efforts to involve non-Federal users and potential private sector system operators in developing its transition plan. He announced NOAA's plan to establish a land remote sensing satellite advisory committee to continue to receive advice from the private sector.

Frank stated that NOAA envisioned a two phase development plan for a civil operational land remote sensing system. The first phase would be an interim system consisting of Landsat D with any necessary follow-on satellites and ground system improvements. This would provide continuity for users of the system. During this phase, advanced remote sensing technology (multilinear arrays) would be developed for the second phase of the program to meet higher performance standards. He anticipated that such a high quality system could be in place no earlier than 1989. This latter system, according to Frank, had been designated the "fully operational system." NOAA would manage the interim operational system with the goal of eventual private sector ownership and operation of the fully operational system.

NASA was represented by Anthony Calio, who stated that under the transition plan, NASA would remain responsible for development of new and advanced technology, satellite systems and prototype operational spacecraft, and where appropriate, would continue to develop and share with users technologies for acquiring, processing, and interpreting remote sensing data.

(5) Space policy legislation in the House: H.R. 4316 and H.R. 6304.—Although no legislation specifically concerning operational land remote sensing satellite systems was introduced in the House during the 96th Congress, two bills dealing with space policy in general were introduced.

On June 5, 1979, Representative Robert Dornan introduced H.R. 4316, the National Space Policy Act of 1979. The bill was identical to S. 3599, the space policy bill originally introduced by Senator Schmitt in the 95th Congress. It included the goal of establishing a World Information System by the year 1990, incorporating an operational earth resources monitoring system.

Representative George Brown introduced his National Space Policy Act of 1980, H.R. 6304, on January 28, 1980. Based primarily on Senator Stevenson's bill (S. 244), the Brown bill had several changes which emphasized international remote sensing operations. The bill called specifically for the development of an improved capability for interpretation and rapid utilization of remote sensing data and the investigation and determination of institutional arrangements for international cooperation in the use of remote sensing systems, including the fullest possible declassification of satellite monitoring and surveillance data, and provision for increased training in data interpretation.

No hearings were held specifically on either of these bills, although the House Science and Technology Committee held general hearings on space policy in July 1980.[60] These hearings did not focus on remote sensing.

(6) S. 3169.—In the closing days of the 96th Congress, Senator Stevenson introduced S. 3169, the Earth Data and Information Service Act of 1980. The bill was essentially the same as S. 663, but would have established the Service within NOAA instead of NASA. No action was taken on the bill.

e. 97th Congress, 1st session (1981).—During the first session of the 97th Congress, no legislation concerning an operational remote sensing satellite was introduced in either the House or Senate. Joint hearings were held on this topic in July 1981. Two space policy bills were introduced, and the House committee held space policy hearings in the fall of 1981, but these did not focus on remote sensing systems.

(1) 1981 joint House/Senate hearings.—On July 22 and 23, 1981, the Senate Commerce, Science, and Transportation Committee's Subcommittee on Science, Technology, and Space jointly held hearings with the House Science and Technology Committee's Subcommittee on Space Science and Applications on civil land remote sensing systems.[61]

The most notable aspect of these hearings was the proposal by Comsat, represented by its President, Joseph Charyk, that the Government make Comsat the designated entity for taking over remote sensing systems. The Comsat proposal included not only land remote sensing, but weather satellites as well. Charyk explained that the advantages of combining the two systems resulted from economies of scale by eliminating duplicate facilities and from the nature of the data which would be produced. The Comsat proposal, called Earthstar, would have effected transfer of remote sensing satellite systems to the private sector by purchase of certain elements of the GOES, NOAA, and Landsat satellites and certain related ground equipment from the Government. Charyk averred that this proposal could save the Government "several hundred million dollars in operating costs" and "users would benefit from our plans to improve the timeliness of data and increase the diversity of data products." He also noted that a "Government commitment to procure its data and data products from the commercial system is required."[62]

Representatives of the American Science and Technology Corporation [ASTECH] explained their proposal to take over operation of remote sensing satellites. According to Dr. Norman McLeod, the Astech proposal, called FOODSAT/PETROSAT, would focus on providing information for managing those resources. The concept envisions operation of the space and ground segments by the private sector, with continued R&D by NASA, NOAA, and the university research community. Astech would launch several small satellites, using multispectral scanners, into sun-synchronous orbits to produce many observational opportunities in the morning and afternoon hours. Data would be received at existing Landsat ground stations and processed with existing data processing systems. The satellites would use existing technology to meet the needs of an existing market, according to McLeod, and therefore could be expected to produce an adequate return without direct Government subsidies. McLeod emphasized the need for a guarantee that the Government would not launch competing systems, however, and listed several areas in which Government support would be needed, such as in international marketing through Embassy support of visits to foreign capitals, continued basic and applied research in the Government and universities, and the continuation of training programs.

---

[60] U.S. Congress. House. Committee on Science and Technology. Subcommittee on Space Science and Applications. "United States Civilian Space Policy." Hearings. 96th Congress, 2d session, July 23, 24, 1980. Washington, U.S. Government Printing Office, 1980. 246 pp.

[61] U.S. Congress. House. Committee on Science and Technology. Subcommittee on Space Science and Applications. Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Science, Technology, and Space. "Civil Land Remote Sensing Systems." Hearings. 97th Congress, 1st session, July 23, 1981. Washington, U.S. Government Printing Office, 1981. 366 pp.

[62] Ibid., pp. 260–272.

Thomas Anderson, representing the National Conference of State Legislatures, expressed concern that if the private sector took over complete operation of the program, costs could rise prohibitively. He added that it might be possible to turn over the ground segment without adversely affecting data prices, and that "it may well be that the time is right to transfer this segment into private hands." [63]

Michael T. Halbouty, a geologist and engineer, asserted that Landsat should have been declared operational years ago so that the technology could have been systematically upgraded to provide data on a routine and efficient basis, and that if such a commitment had been made by the Government, the private sector would be involved in directly marketing Landsat data and perhaps leasing part of the Landsat system today. The designation of NOAA to manage the transition of Landsat to an operational status "compounded and confused" the situation, according to Halbouty, and "it is time to get back on the right track." [64] He recommended that Landsat be declared operational; that the Government be responsible for the high risk elements of the operational program (adding that this is the state of most of the program now, but the Government's share would decline in the future); that industry participation be encouraged by broad, simple legislation and streamlining Government bureaucracy so that industry has to interface with only one agency; and that single agency be responsible for working out details of the institutional and legal framework for maximizing industry involvement. He also urgently recommended that the United States launch a solid state stereo remote sensing satellite.

General Electric Co., which constructs the Landsat satellites for NASA, was represented by Mr. A. J. Rosenberg, who expressed concern about the lack of commitment to continuity for the Landsat program. In his opinion, only one organization, the U.S. Government, could make such a commitment, and once continuity is assured, then other issues, such as the feasibility of operating the system commercially, can be addressed. He expressed doubts that the system could be operated commercially at this time, and urged that the focus be on preserving "the integrity of the system we have" and protecting "our national investment." [65]

---

[63] Ibid., p. 73.
[64] Ibid., p. 208.
[65] Ibid., p. 235.

Other witnesses complained that there still was no assurance of continuity of the system, and that without such assurances, the United States could lose out on satellite remote sensing entirely, because other countries are developing similar systems.

(2) Space policy legislation: H.R. 3712 and H.R. 4286.—Two general space policy bills were introduced. The first, H.R. 3712, was introduced by Representative George Brown on May 28, 1981. The bill is identical to H.R. 6304 from the previous Congress.

On July 28, 1981, Representative Newt Gingrich introduced H.R. 4286, the National Space and Aeronautics Policy Act of 1981. The bill is patterned after the Schmitt bill from the 96th Congress (S. 212), and its provisions regarding remote sensing are the same.

No hearings were held on either bill. General space policy hearings were held by the House Science and Technology Committee in September 1981, but these did not focus on remote sensing.[66]

5. User requirements

In developing an operational system, it is important to identify the needs of potential users of the data so that the system will meet a broad scope of requirements. One criticism of NASA's experimental Landsat program is that it was designed with the needs of the agricultural community in mind, and not other sectors, such as geology.

NOAA is attempting to remedy the situation for the operational Landsat program, and as noted earlier, has established an advisory committee composed of individuals from industry, academic, and State governments to obtain their input in managing the system.

a. NOAA's findings.—The NOAA policy document submitted to Congress in June 1980 identified some of the expected user needs to be met by an operational system. The agency concluded that the following performance standards were needed for a high quality operational system:

> Sensors designed to generate data meeting a broad range of user requirements at a reasonable price;
>
> Assured continuity of satellite coverage without break, with one backup satellite in orbit at all times and another on the ground;
>
> 95 percent confidence that, averaged over the 2-day period, all data will be processed and made available from the ground station within 48 hours of receipt; and
>
> Ability to identify and process certain data out of order to meet urgent user needs.[67]

NOAA had conducted a preliminary survey of user requirements for this policy document, which indicated that "agencies interested in renewable resource applications such as agricultural crop assessment want frequent observations, delivery of data within 48 hours in certain circumstances, spectral bands that discriminate between various types of vegetation and resolution higher than that provided by the current Landsat system." Users requiring data for land use management and environmental observations, on the other hand, "request higher resolution over urban and suburban areas and time-series analyses to detect detailed changes." The geological community, especially companies interested in mineral extraction, require "stereoscopic capabilities, global coverage, 30- to 40-meter resolution and processing of data within a few weeks." [68] Table 5-5 summarizes NOAA's findings regarding user requirements in an operational land remote sensing satellite system.

---

[66] The hearings were held on Sept. 21, 22, and 23, 1981, by the Subcommittee on Space Science and Applications. They had not been published as of December 1981.

[67] U.S. Department of Commerce. National Ocean and Atmospheric Administration, op. cit., p. 5.

---

[68] Ibid., p. 6.

TABLE 5-5
SUMMARY OF POSSIBLE REQUIREMENTS FOR LAND REMOTE SENSING (All Domestic Users)
(Based on Available Data as of April 1, 1980)

Performance Parameter	PROGRAMMATIC CATEGORY GROUPS Renewable Resources	Non-Renewable Resources	Planning/Environmental Management
Spatial Resolution (Meters)	Range 2-80 m; 10-30 m Most Useful 2-30 m meets 90% of Requirements[1]	Range 3-100 m; 30-80 m Most Useful 3-30 m meets 30% of Requirements	10-80 m; 10-30 m Most Useful
	10-30 m meets 81% of Requirements 15-30 m meets 80% of Requirements[4]	10-30 m meets 28% of Requirements 15-30 m meets 26% of Requirements[1]	10-30 m meets 60% of Requirements 15-30 m meets 50% of Requirements[4]
	30-80 m meets 10% of Requirements	30-80 m meets 70% of Requirements	30-80 m meets 40% of Requirements
Spectral Bands	MSS/TM Type Plus Microwave	MSS/TM Type Plus Microwave	MSS/TM Type
Timeliness (Observation to User, Days)	2 Days – 15%[2][3] 2-7 Days – 50% 7-30 Days – 35%	30 Days 100%	2-7 Days – 40%[2][3] 7-30 Days – 60%
Repeat Coverage Cycle (Days)	5-7 Days – During Growing Season Seasonal at Other Times[3]	Seasonal	Seasonal
Area Coverage	Global Capability	Global Capability	Domestic Capability
Stereo Coverage	Needed for 20% of the Requirements	Needed for 35% of the Requirements	Needed for 15% of the Requirements
Estimated Annual Data Volume (185 KM Square Scenes)	22,000 to 29,000	15,000 to 19,000	4,000 to 6,500

[1] Percentage determined largely from expressed agricultural requirements. Other applications, as they become known, would cause [illegible] limited increase.

[2] Very rapid data delivery is required for observations over areas affected by major hurricanes, floods, earthquakes, pollution events, and similar episodes.

[3] Most critical requirements are for data which is used by the government or industry in regional or global crop condition assessment and production forecasting.

[4] Estimate by NOAA based on incomplete information in user requirements data base. Cost and complexity for adding a single channel at 10 m instead of 15 m is under evaluation.

Source: U.S. Department of Commerce. National Oceanic and Atmospheric Administration. Planning for a Civil Operational Land Remote Sensing Satellite System: A Discussion of Issues and Options. Rockville, Md., NOAA, June 20, 1980. p. 42.

BEST COPY AVAILABLE

b. Improving Image Resolution.—As the NOAA survey indicated, one of the areas which interests users of remote sensing data is the image resolution of the sensors onboard the satellites. The Thematic Mapper on Landsat D and D′ will have 30-meter resolution, meaning that it can distinguish objects that are 30 meters in diameter or more. This is the best resolution to date in the Landsat program, although the Earth Resources Experiment Package carried on board Skylab (described in volume I, chapter 6) reportedly acquired 35,000 frames of photographs with 17-meter resolution, and some photographs might have had 7-meter resolution.[69] There are rumors that early photographs taken by the astronauts were of such high resolution that the Department of Defense [DOD] insisted that they be withheld from public release, or that the photographs were purposely blurred to conceal the level of detail that could be discerned from orbit.[70]

Civil users of remote sensing data who wish for better resolution have claimed for years that DOD will not allow civil remote sensing systems to have very high resolution. While this has never been openly acknowledged by the Government, PD-37 included language stating that advances in image resolution would be permitted "when such needs are justified and assessed in relation to civil benefits, national security, and foreign policy." Whatever explicit language was used in PD-37 identifying the level of resolution which the military sector considers acceptable is classified, but since NASA is currently developing advanced sensors with 10-meter resolution, it could be assumed that this meets with DOD approval.

Charges have also been made that the Office of Management and Budget [OMB] has taken actions that limit resolution on civil satellites. One explanation is that OMB is simply attempting to control how much NASA spends on advancing remote sensing technology, while another is that OMB is acting on DOD's behalf by claiming that civilian development of advanced sensors would be a duplication of services.[71]

A related question is the release of military reconnaissance photographs for use by the civil sector. One argument against this action is that the military sensors are quite different from what civilians would want to use—military sensors are looking for specific manmade objects, while civil sensors are looking for large scale natural features or manmade effects on natural resources, such as pollution. According to this point of view, the military reconnaissance photographs and technology would be of little value to civil users.[72] Not all civil users appear convinced by this argument, since at the end of 1981, attempts were still underway to gain access to the military data.

c. Advanced sensors.—User requirements for the future also include the development of advanced sensors for studying the Earth from space. A number of advancements have been identified over the life of the Landsat program, and some developmental work has been performed by NASA. Budgetary constraints have limited these efforts, however. Three expected advancements are: Multilinear arrays, stereo imaging, and a large format camera. Figures 5-1 and 5-2, summarizing the different types of remote sensing technology, are shown on the following pages, and were provided by NASA.

---

[69] David A. Mathisen. "The Unfulfilled Promises of Remote Sensing." New Engineer, June/July 1978, p. 20.

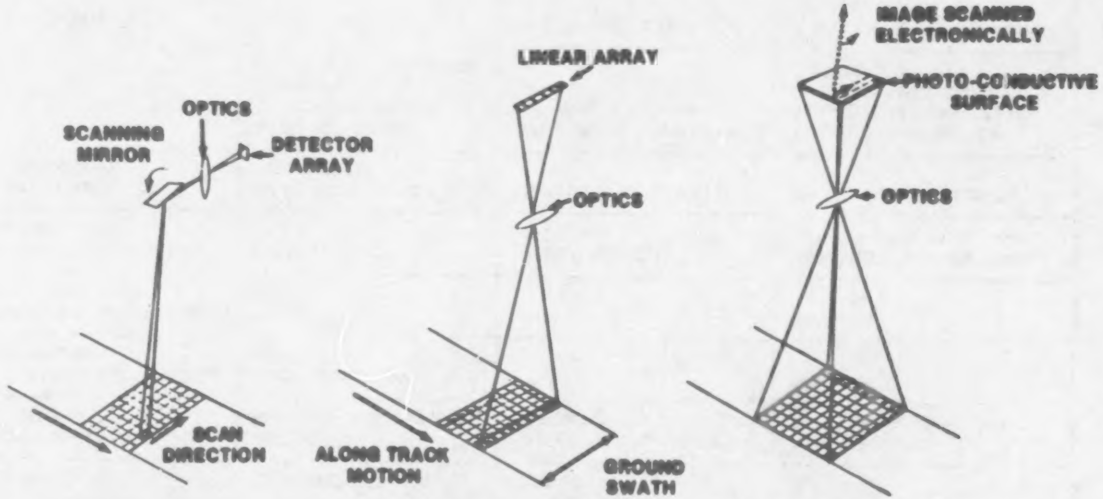
[70] Everly Driscoll. "The Bureaucratic Odyssey of a Space Mapping Camera." Science News, Nov. 27, 1971, p. 363.

[71] Mathisen, op. cit.

[72] James Welch, NASA Office of Space and Terrestrial Applications. Private communication, March 1982.

FIGURE 5–1

COMPARISON OF SCANNING SYSTEMS FOR EARTH OBSERVATIONS


SCANNING MIRROR
OPTICS
DETECTOR ARRAY
SCAN DIRECTION
LINEAR ARRAY
OPTICS
ALONG TRACK MOTION
GROUND SWATH
IMAGE SCANNED ELECTRONICALLY
PHOTO-CONDUCTIVE SURFACE
OPTICS

WHISKBROOM SCANNER
(MSS, TM)

PUSHBROOM SCANNER
(SPOT, STEREOSAT, MAPSAT, MLA)

FRAMING CAMERA
(RBV, LFC)

BEST COPY AVAILABLE

FIGURE 5–2

TRADEOFF: TM/ SCANNER VS MLA/ PUSHBROOM

KEY TECHNOLOGY ELEMENT	REQUIREMENT	TM/SCANNER	MLA/PUSHBROOM
WEIGHT	LIGHTWEIGHT	900 LBS	200 LBS (?)
• OPTICS FOV AND RESOLUTION	15 DEGREES 30M GROUND RESOLUTION	NFOV RICHEY-CRETIEN 40 CM APERTURE	NEW WFOV DESIGN 20 TO 40 CM APERTURE
• ELECTRO-MECHANICAL SCANNER	15 DEGREES FOV COVERAGE	YES	NO
• FOCAL PLANE ARRAY PERFORMANCE	NEΔρ NEΔT	SNR = 1	SNR = 20
• FOCAL PLANE ARRAY COMPLEXITY	COVER THE FIELD	100 DETECTOR CHANNELS	6920 DETECTOR CHANNELS PER COLOR X 7 COLORS
• INSTRUMENT BANDWIDTH	REAL TIME: 25 SEC PER PICTURE	DWELL TIME = 10μSEC	DWELL TIME = 4 MSEC
• MULTIPLEXER	REDUCED INTER-CONNECT BETWEEN FOCAL PLANE AND ELECTRONICS PACKAGE	MUX 100 CHANNELS INTO TELEMETRY CHANNEL	FOCAL PLANE AND OFF-FOCAL PLANE MUX OF SEVERAL THOUSAND DETECTORS
• A/D RESOLUTION	0.3% ACCURACY	8 BITS (LINEAR)	8 TO 12 BITS (DUE TO GAIN VARIATIONS)
• RADIOMETRY	ABSOLUTE AND RELATIVE ACCURACY OF 1°C	CALIBRATION SOURCE EVERY SCAN (60 MSEC)	CALIBRATION AFTER EACH PICTURE (25 SEC)
• CALIBRATION SOURCE	VISUAL AND IR BLACK BODY	FIBER OPTICS AND BLACK BODY WITH ELECTRO-MECHANICAL SHUTTER	PUPIL ILLUMINATION WITH ELECTRO-MECHANICAL SHUTTER

BEST COPY AVAILABLE

(1) Multilinear Arrays.—The next advancement in land remote sensing is the multilinear array [MLA]. These devices are available already on the commercial market for uses such as in facsimile reproductions. There are indications that the Soviets have already flown an MLA for remote sensing purposes and Germany has developed an instrument which will fly on the space shuttle in 1983 using this technology. The first free-flyer in the West using this technology will be the French SPOT satellite in 1984. (See section E.2. for further discussion of these programs.)

As described earlier, scanners use mirrors which oscillate back and forth to produce images, with the individual sensors imaging the surface below sequentially (called "whiskbroom" technology). Thus, each sensor "time shares" one sweep of the scanner, and the amount of time each sensor has for imaging (its "dwell time") is very short. Multilinear arrays on the other hand, have each of their 6,000 sensors simultaneously image the surface below, taking one linear image at a time (termed "pushbroom" technology). Since these sensors take their images at the same time, the dwell time is much longer. For example, according to Ken Ando of NASA, an MLA sensor operating at the same resolution as the thematic mapper (30 meters) would have a 400-fold dwell time advantage. Other advantages of MLA technology include the absence of moving parts during imaging, the ability to operate at variable electronically defined scan rates matched to the ground velocity at various altitudes, and significant growth potential due to its modular nature.[73] The improvement in the signal-to-noise ratio because of the increased dwell time can be used to obtain higher resolution, perhaps as good as 3 meters, although the current NASA technology development program is officially attempting to attain 10 meter resolution with MLA's.[74]

NASA's Goddard Space Flight Center and Jet Propulsion Laboratory are performing R&D on MLA technology at a modest level of funding (a total of approximately $10 million per year). Although NASA does not have an approved program to fly MLA sensors, such an effort may be requested as a new program start in fiscal year 1984. Initially, the sensors might be flown on the shuttle, with later transition to a free flyer.

(2) Stereo Imaging: Stereosat and Mapsat.—One application of MLA technology is stereo imaging, which provides three-dimensional imagery, instead of the two-dimensional imagery available from existing Landsats. Two or more images are taken from different angles, from which the user can infer the relative height of topographic features. This is particularly useful for geological applications, but can also be utilized in other areas of remote sensing analysis.

The French satellite, SPOT (see section E.2.) will be the first land remote sensing satellite capable of stereo imaging. The United States has considered development of stereo technology for several years, and two programs (Stereosat and Mapsat), were planned, but have not been initiated.

---

[73] Ken. J. Ando. "The MLA Program at NASA." Paper presented to the International Geoscience and Remote Sensing Symposium, June 1-4, 1982, Munich, Germany.

[74] Ken J. Ando, NASA Office of Space Science and Applications, private communication, June 1982.

The utility of stereo imaging was identified by the Applications User Working Group for Landsat D in 1976.[75] Later that year, the Geosat Committee, a group of 100 United States and non-United States international oil, gas, mineral, and geological engineering companies, also identified the needs for such a capability, and included a proposal, named "Stereosat," in its list of potential space missions which would meet their needs.[76]

In November 1976, NASA's Jet Propulsion Laboratory [JPL] began studying the feasibility of a Stereosat mission using an Applications Explorer spacecraft (for other missions in this series, see section II). Working with the Geosat Committee, JPL defined a satellite, using two cameras oriented 23 degrees fore and aft of the nadir, which would be placed in a sunsynchronous orbit providing a swath width of 30 kilometers and an instantaneous field of view of 16 x 19 meters. JPL and Geosat proposed that this be included as a new start in NASA's fiscal year 1979 budget.

NASA did not request funding for Stereosat because of its expected costs and because it did not want to focus on one specific application of remote sensing technology.[77] The Geosat Committee lobbied on behalf of the program, and the House Science and Technology Committee provided $4 million in NASA's fiscal year 1979 budget to begin the program.[78] Ultimately, only $0.5 million was actually included in the NASA's fiscal year 1979 budget, and it was for continuing the JPL studies. In authorizing the $0.5 million, Congress encouraged NASA to proposed Stereosat as a new program in fiscal year 1980, but indicated that it wanted private sector financial support for the program.[79] NASA worked with the Geosat Committee in an attempt to develop sufficient interest among Geosat's members to provide some of the funding, but to no avail.[80]

In the continuation of the studies by JPL, the argument was successfully made by the USGS to add a third nadir-looking camera and to increase the swath width. A revised Stereosat plan was thus developed and issued by NASA/JPL in July 1980.[81]

As finally defined by NASA, Stereosat would have had three cameras, one nadir looking, and two facing fore and aft 23 decrees from the nadir along the spacecraft flight line. Stereo information could be obtained from any pair. The cameras would have used push-broom MLA detectors with 4096 elements. Swath width would have been 61.4 km, and the swaths would have been repeated every 48 days.

---

[75] The history of the Stereosat program is based on: U.S. National Aeronautics and Space Administration. Jet Propulsion Laboratory. Preliminary Stereosat Mission Description. May 30, 1979. Pasadena, Calif., NASA/JPL, 1979. 720-33. pp. 1-1 and 1-2.

[76] F. B. Henderson, III and G. A. Swann. "Geological Remote Sensing from Space;" report of the Ad Hoc Geological Committee on Remote Sensing from Space with recommendations for a GEOSAT program, Flagstaff, Ariz., May 10-14, 1976. Berkeley, Calif., Lawrence Berkeley Laboratory, 1976. p. 1-1.

[77] Aviation Week and Space Technology, Feb. 20, 1978, p. 11.

[78] Aerospace Daily, Mar. 1, 1978, p. 1.

[79] Aerospace Daily, Nov. 28, 1978, p. 114.

[80] Ibid.

[81] NASA/JPL, op. cit., pp. 1-2.

Without funding support from the user community, the program has been terminated.

Mapsat has been proposed by the U.S. Geological Survey and would be specifically designed for cartographic purposes. A conceptual design of Mapsat was prepared for USGS by ITEK Optical Systems Division, teamed with TRW's Defense and Space Systems Group, and was released in December 1979 (an addendum was released in February 1980). The satellite technology would have been very similar to Stereosat, and could have provided map scales at 1:50,000, as well as information for oil and gas exploration. The satellite, using three spectral bands (0.47–0.57 microns, 0.57–0.70 microns, and 0.76–1.05 microns), would have had a resolution of 10 meters.[82]

(3) Large Format Camera.—Apart from multispectral scanners and MLA's, another option in remote sensing is photographic imagery. This has been accomplished on Landsats 1–3 using the Return Beam Vidicon cameras, but no RBVs are included on Landsat D/D′. NASA has developed a Large Format Camera, however, with better resolution (10 meters) than the RBVs which will be flown on the space shuttle as part of the OSTA-3 payload in June 1984. The Large Format Camera will acquire mapping quality photographs with black and white, color, and color infrared film.

The European Space Agency is also planning to fly a Large Format Camera, perhaps with 1 meter resolution, on the space shuttle in 1983 or 1984.

6. Current status of private sector takeover

At the end of 1981, the future of the U.S. civil land remote sensing satellite program was notably uncertain. The directive from the Carter Administration [PD–54] which transferred responsibility for the operational aspects of the program from NASA to NOAA, with eventual takeover by the private sector, was still being implemented, but the emphasis by the Reagan administration had changed to transferring the program to the private sector in the short-term, rather than in 7–10 years as envisioned under PD–54.

As summarized previously, Comsat has proposed that it be made the "designated entity" for operating all U.S. civil remote sensing satellites, including those for meteorological purposes. At the end of 1981, the President's Cabinet Council on Commerce and Trade met to begin considering two questions: the best mechanism for transferring Landsat to the private sector, and if weather satellites should be transferred to the private sector at the same time. The latter question was expected to create some controversy, since civil weather satellites are utilized to some extent by the Department of Defense, and it appeared unlikely that DOD would support transfer of such systems to the private sector. A decision by the Cabinet Council is expected in early 1982.

Other companies rumored to be interested in operating the civil land remote sensing system include: General Electric (which builds the existing Landsat satellites), Hughes Aircraft, Western Union,

---

[82] ITEK Optical Systems Division. Conceptual Design of An Automated Mapping Satellite System [MapSat]. Technical proposal. Prepared for U.S. Geological Survey in response to RFP No. 6398. Dec. 17, 1979. (Also: Technical Proposal Addendum, Feb. 13, 1980).

Lockheed Missiles and Space, TRW, and IBM.[83] All of these assume Government involvement, direct or indirect.

Terra-Mar Associates has indicated an interest in building and operating a totally private land remote sensing satellite system. According to its president, Don Walklet, the market for remote sensing data is significant and satellites using off the shelf technology could be launched for one-fifth the NASA cost (using a privately-developed launch vehicle called Percheron). He estimated the cost of 6–10 launches at $40 million.[84]

The American Science and Technology Corporation [ASTECH] has also developed a proposal for private sector operation of remote sensing systems. As described in the joint House/Senate hearings in the summer of 1981, the concept is called Foodsat/Petrosat and would utilize several small satellites in sun-synchronous polar orbits. Existing Landsat receiving stations would receive the data. According to its sponsors, the concept would use existing technology and fill the needs of an existing market, and would not require Government subsidies (although it would ask for assurances that Government systems would not compete for the same market). This group also plans on utilizing the Percheron launch vehicle for placing its satellites in orbit.

E. INTERNATIONAL ASPECTS OF THE LANDSAT PROGRAM AND SATELLITE REMOTE SENSING

1. International use of Landsat data

Throughout the history of the Landsat program, the United States, through NASA, the Department of State, and the Department of Interior, has sought to share remote sensing data with other countries and to train their scientists in using the data for purposes such as land management. In addition, many foreign countries, including the Soviet Union, purchase Landsat data directly from the EROS data center. Several nations have also constructed receiving stations so that they can acquire Landsat data directly from the satellite.

a. U.S. Government agencies with international involvement.—Three U.S. Government agencies have assisted in providing foreign nations with Earth resources remote sensing information. The U.S. Geological Survey (part of the Department of Interior) has sponsored several international remote sensing training programs at the EROS data center and in foreign countries.

The Department of State is primarily responsible for coordinating remote sensing programs for foreign nations to assure consistent development of the international aspects of the Landsat program. In addition, the Agency for International Development [AID] supports and encourages remote sensing activities in less developed countries [LDCs] by providing: U.S. experts, training, and demonstrations; project grants; financial and technical support for cooperative programs with U.S. industries and institutions; and financial support for formal education in U.S. universities, on-the-job training, and creation of national and regional remote sensing centers. Centers have been established in Nairobi, Kenya, and Ouagadougou, Upper Volta. Another is planned for Bangkok.[85] A summary of the AID program is shown in table 5-6.

---

[83] "Making Landsat a Private Eye." Business Week, June 30, 1980, p. 49.

[84] Quoted in: "California Company Wants to Market Remote Sensing Service Without Government's Help." Satellite News, Aug. 10, 1981, p. 6. The Percheron launch vehicle is being developed by a company called Space Services, Inc. By the end of 1981, one test firing of the rocket had been unsuccessfully attempted; the next is planned for August 1982, and its name is being changed to Conestoga.

---

[85] U.S. National Aeronautics and Space Administration. Office of Space and Terrestrial Applications. "Analysis of the Private Market for Landsat Products and Applications: Final Report." Prepared by OAO Corp. Washington, NASA, Mar. 31, 1981. AID has abandoned plans for centers in Latin America, and the Near East.

Table 5-6.---UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT REMOTE SENSING PROGRAM

GRANTS	PROJECTS	CENTERS	TRAINING
Bangladesh: map areas for third rice crop	Costa Rica: forest survey	Regional:	EROS Data Center
Bolivai: explore iron formations	Bolivia: population census	Nairobi, Kenya	South Dakota State Uni
Cameroon: develop resource management techniques	Senegal: resource inventory	Ouagadougou, Upper Volta	Univ. of New Mexico
Chile: inventory resources	Upper Volta, Togo, Benin: Onchocerciasis (river blindness) - free area survey	Planned:	Argentina
Haiti: measure sugar cane	Morocco: geological mapping	Bangkok, Thailand	Peru
Lesotho: investigate snowfall and drainage patterns	Mali: range management	Cairo, Egypt	Botswana
Pakistan: map river sediment loads for new port location	Kenya: population census (land cover & use)	2 planned in Latin America	Senegal
Peru: identify and map aguaje palm	Bangladesh: weather satellite station	National:	Sudan
Phillipines: assist development of Mindoro Island	Dominican Republic, Jamaica, Costa Rica, Ecuador, Bolivia, Morocco, Thailand, Philippines, and Indonesia: agricultural crop estimates	Cairo, Egypt	Nepal
Sri Lanka: measure rice crop		Tunis, Tunisia	
Swaziland: locate ground water		Kinshasa, Zaire	
Thailand: survey agriculture		Bangkok, Thailand	
Zaire: provide map base		Planned:	
		Younde, Cameroon	
		Damascus, Syria	
		Katmandu, Nepal	

Source: U.S. National Aeronautics and Space Administration. Analysis of the Private Market for Landsat Products and Applications: Final Report. Prepared by OAO Corporation in Response to Task Order 25, Contract No. NASW3358. Washington, NASA, March 31, 1981. p. 5-3.

In addition to the bilateral agreements for Landsat receiving stations (discussed below), NASA encouraged international involvement in Landsat through substantial participation of foreign investigators sponsored and funded by 50 countries and 4 international organizations through 1978 (see table 5-7). These activities involved utilization of data from Landsat 1 and 2 and the Skylab Earth Resources Experiment Package for 163 investigations which were selected by NASA based on scientific merit. NASA provided the data, while the countries performed the experiments and provided the results to NASA. No exchange of funds was involved.

TABLE 5-7

INTERNATIONAL PARTICIPATION IN NASA's EARTH RESOURCES INVESTIGATIONS PROGRAMS*

Argentina
Australia
Bangladesh
Belgium
Bolivia
Botswana
Brazil
Canada
Central Treaty Organization
Chile
China
Colombia
Commission of European Communities
Ecuador
Egypt
European Space Agency
Finland
Food and Agriculture Organization
France
Germany, Federal Republic of
Greece
Guatemala
India
Indonesia
Iran
Israel
Italy
Japan
Kenya
Korea
Lesotho
Libya
Malaysia
Mali
Mekong Commission
Mexico
Netherlands
New Zealand
Norway
Pakistan
Peru
Philippines
Romania
South Africa
Spain
Sri Lanka
Sweden
Switzerland
Thailand
Turkey
United Kingdom
Venezuela
Zaire

---

* Adapted from: NASA. A Review of NASA International Programs As of January 1, 1982. Appendix B.

b. Foreign Landsat Receiving Stations.—At the end of 1981, 10 ground stations to receive and process Landsat data were in operation outside the United States. These stations are in Argentina, Australia, Brazil, Canada (which has two), India, Italy (owned by the European Space Agency), Japan, South Africa, and Sweden (owned by ESA). A station in Thailand is expected to become operational in early 1982. In addition, China and Indonesia have signed memoranda of understanding [MOU's] with NASA to construct receiving stations, and Kenya, Mexico, Nigeria, Romania, and Upper Volta have indicated interest. Three countries (Chile, Iran, and Zaire) had signed MOU's for Landsat receiving stations, but these have lapsed.

The MOU's which are signed in order for a foreign country to gain permission to build a Landsat receiving station stipulate that: (1) none of the costs of the facilities will be borne by the United States; (2) the foreign cooperating agency must provide NASA any and all data desired by NASA (which is of particular importance when the tape recorders on the Landsat satellites fail); (3) the foreign cooperating agency will provide free of charge the data requirements of NASA to selected experimenters, and to the public in the region of its station for reasonable charges; (4) it will pay whatever access fee is required by the United States; and (5) NASA does not guarantee a continuing program.

Initially, there was no charge to foreign nations for receiving data at their ground stations, but in December 1975, NASA notified nations operating or planning Landsat stations that, as provided in the MOU, they would be assessed an access fee of $200,000 per year for the costs of the space segment of the Landsat program. At the end of 1981, NOAA was considering raising the access fee to $600,000.

c. United Nations programs.—The United Nations has a long history of fostering a climate for international sharing of the benefits from remote sensing data. In 1969, the U.N. Committee on Peaceful Uses of Outer Space [COPUOS] established a space applications program, which has sponsored numerous seminars/training sessions on utilizing remote sensing data. A U.N. expert on space applications has also been designated.

During the 1970's, as the satellite remote sensing program progressed and the utility of its data to countries throughout the world became evident, the role of the United Nations grew.[86] Two remote sensing centers have been established, one in the United Nations Center for Natural Resources and Energy Division [CNRED] of the Department of Technical Cooperation for Development [TCD], and the other at the Food and Agriculture Organization [FAO] of the United Nations in Rome. The CNRED/TCD remote sensing unit provides assistance in designing and evaluating remote sensing projects in which satellite data is used, designs programs to integrate remote sensing data into economic development projects, sponsors the establishment and strengthening of training centers, and advises governments interested in using satellite remote sensing data. The FAO unit provides advisory services and technical assistance (including training) to individual countries, provides support to and coordinates activities between FAO headquarters and field programs using satellite remote sensing data, and serves as a liaison between FAO and other organizations concerned with space applications.

---

[86] Information on U.N. satellite remote sensing programs is partially based on: "Role of the United Nations System in Space Activities." Background paper prepared for the Second U.N. Conference on the Exploration and Peaceful Uses of Outer Space. New York, United Nations, Oct. 21, 1981. A/CONF.101/BP/11/Add.1.

A major component of the activities of FAO and CNRED (which are financed through the U.N. Development Program) is providing the equipment necessary to undertake a specific project. Approximately two-thirds of the cost of a project is for equipment.

The U.N. Disaster Relief Organization [UNDRO] is evaluating the potential of using satellite remote sensing data in disaster relief activities. A draft report on the potential role of satellites in disaster relief activities is expected to be released in 1982. The U.N. Educational, Scientific, and Cultural Organization [UNESCO], has several projects related to utilization of remote sensing data, including mineral exploration, hydrology, and oceanic research.

The World Bank, a specialized agency of the United Nations, has two sections which utilize remote sensing data: The Resource Planning Unit [RPU] of the Agriculture and Rural Development Department, and the Cartographic Division [CD] of Administrative Services. The RPU uses data in assessing the feasibility of Bank-financed projects; while the CD uses them for producing or updating small-scale maps for Bank reports.

In addition to these specific activities, COPOUS has served as a forum for a longstanding debate over the legal implications of remote sensing, as discussed in section 4.

d. Issues Concerning Utilization of Landsat Data by Developing Countries.—Examples of actual programs utilizing satellite remote sensing data have been described at length in other publications, so need not be repeated here (for example, the Scientific and Technical Subcommittee of COPOUS publishes reports each year cataloging remote sensing activities throughout the world).[87] Instead, this section will focus on issues connected with utilization of remote sensing data by less developed countries [LDC's].

Charles K. Paul, manager of the Remote Sensing Program for the U.S. Agency for International Development, has written extensively on this topic. In a 1981 article, he and Adolfo C. Mascarenhas of the Bureau of Resource Assessment and Land Use Planning at Tanzania's University of Dar es Salaam, identified six major issues of concern to LDC's. Several of these have been discussed elsewhere in this report, but will be included here for completeness.[88]

The first issue concerns the operational land remote sensing satellite system. Not only does this involve the issue of continuity of the U.S. program past Landsat D/D', but also the arrangements which might be made for an operational (as opposed to an experimental) system. Paul and Mascarenhas delineate the following potential problem areas: Increase in prices for Landsat data products, increase in access fees, and imposition of a copyright on all data products if the system is operated by the private sector (meaning that a fee would have to be paid each time the data were reproduced).

---

[87] The most recent is: "Report of the United Nations Expert on Space Applications to the Scientific and Technical Subcommittee." List of remote sensing applications. New York, United Nations, Jan. 19, 1981. A/AC.105/257/Add.1/Rev.1.

[88] Charles K. Paul and Adolfo C. Mascarenhas. "Remote Sensing in Development." Science, Oct. 9, 1981, pp. 139-145.

A second potential problem area is the international debate over the spatial resolution of images. As detailed elsewhere in this report, some countries want to have the right of "prior consent" over who should be able to receive high resolution images of their land and natural resources because of economic and national security concerns. The U.S. policy is to make all satellite remote sensing data available to everyone on a nondiscriminatory basis. According to Paul and Mascarenhas, "Some Third World countries, ever vigilant regarding resource mapping along poorly defined frontier, are not satisfied with the present U.S. position." [89]

The disparity between information available to mineral-rich countries and that available to multinational firms using satellite technology is another issue identified by Paul and Mascarenhas. According to their thesis, the ability of the mineral-rich nations to utilize remote sensing data to carry out their own surveys may improve the often difficult negotiations between the countries and multinational companies.

Transfer of computer processing techniques to the LDC's is another problem.[90] According to Paul and Mascarenhas,"the limitation of digital image technology to spectral information and the difficulty of learning to use and maintain equipment associated with the technology" have been the primary difficulties encountered in attempts to transfer the technology. The training programs previously described will assist experts from the LDC's in learning how to use the digital system technology.

The last two issues discussed by Paul and Mascarenhas concern the desire of many foreign countries to achieve autonomy in remote sensing data by either (1) building their own receiving stations, or (2) building their own satellites. These are discussed in the next section.

2. Remote sensing satellite systems in other countries

As noted above, some foreign countries have decided to develop their own remote sensing satellite system. Five countries and one international organization are actively pursuing earth remote sensing satellites: the European Space Agency, France, Germany, India, Japan, and the Soviet Union.

a. The European Space Agency.—The European Space Agency [ESA] is a group of 11 member countries which was established in 1975.[91] In the area of satellite remote sensing, ESA decided in 1981 to propose development of the Earth Resources Satellite 1 [ERS-1] to be launched in 1987. The 2.2 ton satellite will be used primarily for ocean sensing, and its primary instrument is planned to be a synthetic aperture radar. Under current plans, it will also carry an ocean color monitor, and a radar altimeter for measuring wave height to within 5 centimeters. ERS-1 is an experimental system, which may be the basis for a multisatellite operational system sometime in the 1990's.

---

[89] Ibid., p. 144.

[90] See also: Charles K. Paul. "Transfer of Remote Sensing Computer Technology to the Developing World—Case Examples." Paper presented to the 1979 Machine Processing of Remotely Sensed Data Symposium. June 27-29, 1979.

[91] The members of ESA are: Belgium, Denmark, France, Federal Republic of Germany, Ireland, Italy, Netherlands, Spain, Sweden, Switzerland, and the United Kingdom. Austria and Norway are associate members, and ESA has a technical agreement of cooperation with Canada.

b. France.—In February 1978, France decided to develop the SPOT satellite which will be launched in 1984. (Belgium and Sweden are also participating in the program.) This will be the first satellite capable of stereo imaging, and will use pushbroom multilinear array technology. The satellite will carry two identical high resolution visible [HRV] instruments with 20-meter resolution in the multispectral mode, and 10 meter-resolution in the panchromatic (black and white) mode.[92] The multispectral instrument will use the green, red, and near-infrared bands. Each instrument will have a ground swath of 60 kilometers, and can be independently pointed either along the vertical or at an angle within ±27° to the east or west of the orbital plane. The instruments can be pointed so as to cover adjacent fields, providing a swath width of 117 kilometers.

Weighing 1,750 kilograms at launch, the satellite will be placed in a near polar, sun-synchronous (98.7°) orbit at 832 kilometers, with a 10:30 a.m. equatorial crossing. Although the orbit will repeat itself only once every 26 days, the pointing capability of the instruments will allow imagery from each area to be gathered every 4 days at the equator, and 2.5 days at 45° latitude.

The data will be transmitted to the ground at 50 megabits per second, and SPOT will have two onboard tape recorders for storing data for later transmission to the central receiving station near Toulouse, France. It is expected that Landsat receiving stations can be modified for a relatively low cost to receive SPOT data as well.

The stereo imaging capability of SPOT, while it will be the only one available for some time, has been criticized because it takes images on successive orbital passes, rather than simultaneously, as would have been possible with a system such as Stereosat.

Because of the high resolution on the panchromatic band (10 meters), France may distribute data from that band only with the permission of the sensed country,[93] although by the end of 1981, a final decision had not been made by the French government. A company called Spot-Image is being established to market and distribute SPOT data and will have French, Belgian and Swedish stockholders. The French space agency, CNES, will have a 36-percent share in the company.

c. Germany.—Germany is developing a remote sensing instrument that will be flown on the space shuttle in 1983. Called MOMS, for Multispectral Optical Modular Scanner, it will use pushbroom multi-linear array technology. MOMS will fly as part of Germany's first Shuttle Pallet Satellite [SPAS-01] payload, and is expected to have 30-50 meter resolution in visible bands, and 100 meter resolution in the infrared. It will be capable of changing swath width between 55, 110, and 240 kilometers, depending on desired resolution.[94]

---

[92] "Satellite-Based Remote Sensing System." Centre National d'etudes Spatiales. Toulouse, France. [n.p.,n.d.]

[93] Charles K. Paul and Adolfo C. Mascarenhas, op. cit., p. 145.

d. India.—The first Indian remote sensing satellite was launched by the Soviet Union in 1979. Named Bhaskara I [or SEO I] it carries two microwave radiometers and a television camera for observations in the visible and near infrared bands. Electrical arcing in the television camera power system led Indian engineers to decide not to activate that system,[95] but both radiometers functioned properly. The satellite was turned off in May 1981.[96]

Bhaskara II [SEO II], another earth resources satellite, was launched for India by the Soviets in November 1981. The satellite carries instruments similar to Bhaskara I.

India is planning a series of advanced remote sensing satellites for the 1980's. Called Indian Remote Sensing [IRS] satellites, the first will carry three Linear Imaging Scanning Sensor [LISS] cameras. Image resolution will be 70 meters with a swath width of 140 kilometers, or 40 meters with a swath width of 180 kilometers.[97]

e. Japan.—At the present time, Japan is planning two remote sensing satellites. The first, MOS–1 (Marine Observation Satellite) is expected to be launched in 1986[98] for observing the ocean. The second, ERS–1 (not to be confused with the ESA satellite with the same designation), will be launched 2 years later and will focus on oil and mineral exploration.

MOS–1 will weigh 750 kilograms, and will be placed in a 909 kilometer sun-synchronous orbit. The satellite will carry four instruments, including a multispectral electronic self scanning radiometer. This instrument will operate in four bands (0.51–0–69 microns; 0.61–0.69 microns; 0.72–0.8 microns; and 0.80–1.1 microns) for providing data on sea-surface color and will have a resolution of 50 meters. The other instruments are a microwave scanning radiometer (for measuring the water content of the atmosphere), a visible and thermal-infrared radiometer (for sea-surface temperature), and a data collection system.[99]

ERS–1 is scheduled to carry a synthetic aperture radar capable of 20 meter resolution, a stereo camera, and visible/infrared measurement systems.[1] The satellite will be the heaviest launched by the Japanese, weighing 1,215 kilograms. Japanese oil, metals, and electronics companies, in cooperation with the Ministry of International Trade and Industry, are establishing an earth resources observation analysis center in connection with the planned ERS–1 program to enhance Japan's computer technology for utilizing spacecraft data for resources monitoring.[2]

---

[94] Craig Covault. Germans Develop Multimission Satellite. Aviation Week and Space Technology, May 8, 1978, p. 55.

[95] David Velupallai. "ISRO: India's Ambitious Space Agency." Flight International, June 28, 1980, p. 1466.

[96] Government of India. Department of Space. Annual report 1981–82. Bangalore, India, 1982. p. 4.

[97] Ibid., p. 14.

[98] Launch was originally planned for 1984, but has been slipped to 1986.

[99] National Space Development Agency of Japan. Marine Observation Satellite-1, (MOS–1). September 1980.

[1] "Japanese Gain Capabilities in Advanced Space Effort." Aviation Week and Space Technology, Mar. 9, 1981, p. 107.

[2] Aviation Week and Space Technology, Aug. 17, 1981, p. 15.

An Earth Observation Center [EOC] already has been established in Japan for using Landsat data. When Japan begins launching its own satellites, the center will be used as a mission control center, and the receiving/processing center.

f. Soviet Union.—Like the United States, the first earth resources observation data collected by the Soviets was accomplished using manned vehicles, beginning with Soyuz 9 in 1970. Today, remote sensing instruments are flown as part of the Kosmos program, the Meteor weather program, and the manned space station program.

Beginning in 1979, the Soviets began launching satellites in the general Kosmos series which are indistinguishable from military reconnaissance satellites in terms of their orbital characteristics and telemetry. Launched into 82.3° inclination orbits, the TASS announcement accompanying these launches identifies the payload as having an earth resources purpose. No further information is available on what type of data is received.

The Meteor program has been used to fly sensors for land and ocean remote sensing since approximately 1978. Satellites launched in the Meteor 2 series have been identified as carrying new remote sensing sensors. Information on the components and characteristics of Meteor-2 vehicles is shown in table 5–8.

TABLE 5-8

EQUIPMENT COMPONENTS AND CHARACTERISTICS OF ON-BOARD INFORMATION COMPLEX OF "METEOR-2" VEHICLE

Equipment	Spectral Bands (Microns)	Coverage (kilometers)	Resolution (kilometers)
Scanning telephotometer for direct imaging	0.5 - 0.7	2100	2
Scanning telephotometer for global coverage	0.5 - 0.7	2400	1
Scanning IR-radiometer for global coverage	8-12	2600	8
Scanning IR-spectrometer	8 channels in bands of 11,10-18, 70	1000	30

Source: Union of Soviet Socialist Republics. National Paper: USSR. Prepared for Second United Nations Conference on Exploration and Peaceful Uses of Outer Space. New York, United Nations, September 2, 1981. A/CONF.101/NP/30. p. 23.

In June 1980, the Soviets launched a Meteor satellite which carried a 600 kilogram experimental sensor system including several different scanning devices: a multispectral mechanical scanning device with medium resolution [MSR-RA], a multispectral electronic scanning scanning device with high resolution [MSU-VA], and a multispectral system designated Fragment 2. These instruments are prototypes for later use on a continuously operating quick-look subsystem for observing characteristics of rapidly-varying changes in the natural environment.[3] The characteristics of these systems are shown in table 5-9.

---

[3] Ibid., pp. 18-19.

TABLE 5-9

MAIN CHARACTERISTICS OF MSU-SA, MSU-VA DEVICES AND "FRAGMENT-2" SYSTEM

Equipment	Spectral Band (Microns)	Coverage (kilometers)	Field, diaphragm projection on the earth surface at nadir (meters)
Multispectral scanning equipment with mechanical scan MSU-SA	1.5 - 0.6 0.6 - 0.7 0.7 - 0.8 0.8 - 1.0	600	170
Multispectral equipment with electronic scanning, MSU-VA	0.5 - 0.7 0.7 - 0.8 0.8 - 1.0	30	30
Multispectral scanning system Fragment 2	0.4 - 0.8 0.5 - 0.6 0.6 - 0.7 0.7 - 0.8 0.7 - 1.1 1.2 - 1.3 1.5 - 1.8 2.1 - 2.4	85	80

Source: Union of Soviet Socialist Republics. National Paper: USSR. Prepared for the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space. New York, United Nations, September 2, 1981. A/CONF.101/NP/30

A new class of satellites, designated Meteor-Priroda, appeared in 1981. Priroda is the Russian word for nature, and is the name of the central earth remote sensing facility in the Soviet Union. The Meteor-Priroda spacecraft is three-axis stabilized, and placed into a sun-synchronous orbit at 600–650 kilometers. The satellite carries two multi-spectral television-type devices, designated MRTVK. One operates in four spectral bands (0.5 to 0.6 microns; 0.6 to 0.7 microns; 0.7 to 0.8 microns; and 0.8 to 1.1 microns) with 1,930 kilometer coverage and 1 x 1.7 kilometer resolution. The other operates in two bands (0.5 to 0.7 microns, and 0.7 to 1.1 microns) with 1,380 kilometer coverage and 240 meter resolution.[4]

Remote sensing observations were also carried out using equipment on the Salyut 1, 4 and 5 space stations, but the most extensive surveys have been conducted using the MKF-6 multispectral camera on board the Salyut 6 space station, which was launched in 1977 and was still functioning at the end of 1981. The MKF-6, with

---

[4] Union of Soviet Socialist Republics. National Paper: USSR. Paper prepared for the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space. New York, United Nations, Sept. 2, 1981. A/CONF. 101/NP/30. p. 24.

6 spectral bands (0.46 microns, 0.64—0.50 microns, 0.52—0.56 microns, 0.58—0.62 microns, 0.64—0.68 microns, 0.70—0.74 microns, and 0.78—0.86 microns) is built by East Germany, and was flight-tested on the Soyuz 22 mission in 1976. It has been reported that on Salyut 6 the instrument provides data with 20 meter resolution,[5] but that when it was flown on Soyuz 22, permitted 10 meter resolution.[6] The MKF-6 permits 60 percert overlap of adjacent areas, and thus provides stereo images.

Salyut 6 also has a topographical camera designated KATE-140 which is used for contour maps. Other cameras may also be used for remote sensing and/or reconnaissance.

Two specialized interdepartmental centers have been established for receiving and processing remote sensing data: the State Scientific-Research Center for the Study of Natural Resources of the State Committee of Hydrometeorology and Environmental Protection, and the State Scientific-Research and Production Center "Priroda" of the Chief Administration of Geodesy and Cartography of the Council of Ministers of the U.S.S.R. The Soviet Academy of Sciences and the Academies of Sciences of the Soviet Socialist Republics carry out research programs connected with utilizing the data.

The Soviets also have a program for remote sensing of the ocean. Experiments on Meteor satellites and manned flights have reportedly been used for this purpose, along with the land remote sensing experiments. In addition, the Soviets have launched a few Kosmos satellites with ocean resources missions. The first to be clearly identified by the Soviets as having this purpose was Kosmos 1076, launched in February 1979, and it was announced that the spacecraft carried two telescopes aimed at the ocean. In January 1980, a second oceanographic mission was launched (Kosmos 1151) and during 1981, two missions with similar orbital characteristics were placed in orbit, although they were not officially identified as being related to ocean resources sensing (Kosmos 1300 and 1328).

3. *Proposals to establish an international satellite remote sensing system*

With the growing number of remote sensing systems in development by various countries, several issues have arisen concerning methods of making the systems compatible, or possibly combining them into an internationally operated system. In some cases, the discussion concerns operation of the space and ground segments by an international body, while in others, the space segment would remain under national control, but data dissemination would be primarily effected by the international organization.[7] In hearings before the House Science and Technology Committee in 1978, for example, Klaus Heiss proposed creation of a Global Resources Information Center to assure the nondiscriminatory access by all nations to civil space observations by the United States, in conjunction with other nations.[8]

---

[5] Theo Pirad. "Salyut 6 Space Station: Three Years in Orbit and Still Operational." Space Age Review, September-October 1980, p. 3.

[6] Aviation Week and Space Technology, Jan. 2, 1978, p. 11.

[7] Various options for establishing a global satellite observation system are examined in: Valerie Hood, Mary E. Kimball, and David A. Kay. "A Global Satellite Observation System for Earth Resources: Problems and Prospects: A report to the National Science Foundation on the Application of International Regulatory Techniques to Scientific/Technical Problems." St. Paul, West Publishing Co., 1977.

Steps have already been taken to increase the compatibility of remote sensing satellite systems. The United States and France, for example, have worked together to insure maximum compatibility between Landsat and SPOT, so that data from either series of satellites can be acquired by the same equipment.

a. Increasing the role of the United Nations.—As described previously, the United Nations has had a steadily increasing role in remote sensing, and it has been suggested that its activities grow even further. The United Nations could operate its own remote sensing satellites and distribute the data under whatever terms the United Nations could agree upon. If the United Nations were to operate both the ground and space segments, the cooperation of technically advanced countries would be necessary, both in terms of technical expertise and funding.

Alternatively, since purchase and operation of satellites is expensive, the United Nations could ask to receive data from satellites operated by other countries, and serve as a data dissemination point only.

The feasibility of a U.N. Data Dissemination Center has been studied by COPUOS. A 1976 report concluded that:

> An international centre could perform a substantial role in several areas. It could provide satellite remote sensing data, equipment and expertise for training courses . . . taking as its point of reference the effective application of all forms of remote sensing to particular natural resource development topics. It could . . . contribute in an important way to the rendering of technical advisory services to Governments in establishing infrastructure and in the promotion of regional use of receiving stations but its most important role would be in encouraging the effective use of satellite remote sensing as another powerful tool in natural resources development and management.[9]

According to the report, the center would have four main functions: (1) to catalog, store, and interpret remote sensing data, providing facilities for examination by interested parties; (2) to circulate available information and to direct requests by countries for remote sensing data to proper sources; (3) to provide impartial advice and assistance to technical assistance projects, member States and United Nations bodies; and (4) to organize specialized training courses for users, managers, and decisionmakers.[10]

b. U.N. affiliate organization.—Instead of having remote sensing systems (space and/or ground segments) operated by the United Nations itself, it might be possible to establish an affiliate organization similar to the World Meteorological Organization. The development of the global meteorological satellite system in existence today is based on satellites that are paid for entirely by the launching country and inexpensive ground stations that are paid for by the user nation. Presumably, a U.N. affiliate operational satellite program for land remote sensing would also rely on the effort of member States to develop and operate the global system, while its role would be coordination and setting policy and standards guidelines. Such an arrangement would relieve the United Nations of the heavy financial burden implicit in owning and operating any part of the system. Again, however, policies such as access to remote sensing data would be set by the United Nations, not by individual countries such as the United States.

---

[8] U.S. Congress. House. Committee on Science and Technology. Subcommittee on Space Science and Applications. "Panel Discussions on International Space Activities." Hearings. 95th Congress, 2d session, June 20, 21, 1978. Washington, U.S. Government Printing Office, 1978. p. 141.

[9] "Feasibility Study on a Possible Co-ordinating Function for the United Nations in Future Operational Activities in Remote Sensing from Satellites: Revised Concept." Prepared by the Secretariat for the Scientific and Technical Subcommittee of the Committee on Peaceful Uses of Outer Space. New York, United Nations, Oct. 15, 1976. A/AC.105/154/Add.1. p. 7.

[10] Ibid., p. 8.

c. New international organization.—An international system for remote sensing could be patterned after Intelsat or Inmarsat (see chapter 3). Like Intelsat, such an organization could be created as an administrative body including an assembly in which all members would be represented; an executive council, having as permanent members those nations with the largest investment shares in the space segment as well as a number of members elected for a 3-year period to represent regional global interests; and a permanent staff under the direction of a Secretary-General. Actual management could be entrusted to a corporation. Both the corporation and the organization could be financed in a mutually agreed upon manner by the member countries.

One problem with this scenario is that the economic potential of remote sensing data has not been proven yet. When Intelsat was established, it was clear that the market potential for transoceanic communications was sufficient to pay for the cost of the system. While there appears to be evidence that benefits from remote sensing outweigh the costs, all experiments in this field have been heavily subsidized. In addition, the major customers for Landsat data are governments rather than individuals, companies, or agencies (who are the customers for communications services). Thus it remains unclear as to whether the technology can pay for itself, and it may therefore be difficult to establish a self-sustaining operational international commercial land remote sensing satellite system.

d. Potential problems with international operations.—If land remote sensing systems are turned over to an international body for operation, several issues will have to be resolved.

The first of these will be policy regarding distribution of high resolution data. This debate is discussed further in the next section. Almost assuredly, however, the United States would have to accept a compromise to its policy of open dissemination to everyone.

A second potential problem is that an individual country like the United States might lose some degree of political and technical control over the system. For example, although international participation has been an important part of the Landsat program, the United States developed the system primarily for domestic use, and technical and policy considerations based on U.S. policy. In an international scheme, however, other member countries will undoubtedly want to participate in the process of deciding how satellites should be designed, when and where they should be deployed, what kinds of equipment they should carry, and what functions they should perform. Such international participation could compromise the domestic services rendered to American users.

An illustration of this issue can be taken from experience in the development of the meteorological satellite program. When the United States substituted scanning radiometers for video cameras on its weather satellites, a number of countries complained because information extraction was easier with the camera than with the radiometer. The radiometer yielded more valuable data, however, which is why the United States wanted to change instruments. The United States decided to proceed with the radiometer despite international objections, and the utility of the radiometer has proven itself over the years. If the choice had been made by consensus of the international organization, however, technical conservatism may have prevailed.[11]

International management may also prolong the decisionmaking process, which could slow the pace of technological development and innovation. Another risk is politicization in that a group of nations may seek to bar another nation from participating in the benefits of an internationalized system for purely political reasons.

4. *International legal problems associated with satellite remote sensing*

For the past decade, the United Nations has served as the focal point for the debate over international legal issues associated with satellite remote sensing systems. The primary focus of the debate is over who should have access to the data generated by satellite systems, and has become increasingly controversial as the resolution of the satellite sensors has increased.[12]

a. Earth Resources Versus Meteorological Data.—Although many comparisons have been made between meteorological and Earth resources satellites, an examination of the different potential uses of the data from each will reveal why the dissemination of Earth resources data has generated such intense controversy while distribution of weather information has remained apolitical.

For many years, weather information has been viewed as a truly international concern. Since weather patterns do not respect State boundaries, the exchange of meteorological data has long been considered vital for the protection of life and property. Thus, the creation of the first operational weather satellite system encountered virtually no political resistance.

In contrast, the establishment of Earth remote sensing satellites has triggered a great international political debate. The controversy concerns the nature and uses of satellite data. While meteorological satellites monitor global atmospheric phenomena, the target of Earth resources satellite imagery is sovereign territories, and whereas meteorological information may be vital for timely flood and storm warnings, Earth resources data can have longer range and strategic political and economic significance. Some nations, therefore, fear that other nations will use Earth resources data for purposes of economic exploitation. Specifically, they are concerned that foreign governments, companies or individuals with superior satellite technology (either in terms of the capability of the satellite system itself or data processing capability in analyzing the data provided by the satellite), might be able to learn more about the resources of a country than can the government and people of that country.

---

[11] R. M. White. "The Environmental Satellite: What It Means for Man." Administrator, National Oceanic and Atmospheric Administration, in: "The Impact of Space Science on Mankind, Nobel Symposium." New York, Plenum Press, 1976.

[12] For a full discussion of these issues see: Nicolas Mateesco Matte and Hamilton DeSaussure. "Legal Implications of Remote Sensing From Outer Space." Holland, A. W. Sijthoff-Leyden, 1976. 197 pp.

b. Image Resolution and Prior Consent.—As noted previously, the best resolution available with unmanned satellites today is 40 meters (using the Landsat 3 return beam vidicon cameras), but this will improve to 10 meters when SPOT is launched in 1984. Manned systems on Skylab and Salyut have returned data with resolution of 10 meters or less. Although no information is available in the open literature on the resolution of military satellites, it is thought to be less than one meter, and as the resolution of civil remote sensing satellites approaches that capability, governments are increasingly concerned about purposes for which the data could be used. Thus, some countries want the right of "prior consent" over who should be given access to data about their national resources.

As discussed earlier, U.S. policy regarding dissemination of data is the open skies policy (everyone has equal access to the data), while France has announced that it may follow the principle of prior consent for dissemination of data with 10-meter resolution (but not the 20-meter resolution from its multispectral instrument).

The Soviet Union prepared a treaty, which has been signed by itself and other Soviet bloc countries, called the Convention on the Transfer and Use of Data of the Remote Sensing of the Earth From Outer Space. Article IV states:

> A Contracting Party in possession of initial data of the remote sensing of the Earth from outer space, with a better than 50 meters resolution on the terrain, relating to the territory of another Contracting Party, shall not disclose or make them available to anyone except with an explicit consent thereto of the Contracting Party to which the sensed territories belong, nor shall it use them or any other data in any way to the detriment of the Contracting Party.[13]

It should be noted, however, that the 50-meter resolution stated in the convention refers to photographic resolution, which is roughly equivalent to 20-meter resolution using scanners.

c. National sovereignty issues.—The concerns about potential economic exploitation and misuse of satellite data have raised the issue of national sovereignty. One of the basic principles of international law is that each nation holds sovereign rights to natural resources, including the right to dispose of any data concerning these resources. Efforts to protect this sovereignty resulted in the claim that remote sensing was an "earth-oriented" activity and therefore the principle of the freedom of space, embodied in the 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, was not applicable. Consequently, new regulations to govern remote sensing would have to be formulated.

---

[13] Signed in Moscow on May 19, 1978, by Cuba, Czechoslovakia, the German Democratic Republic, Hungary, Mongolia, Poland, Romania, and the Soviet Union. Reprinted in: U.S. Congress. Senate. Committee on Commerce, Science, and Transportation. "Space Law: Selected Basic Documents, Second Edition." Committee print. Washington, U.S. Government Printing Office, December 1978. pp. 489–492.

One such suggestion on governing the new technology included the imposition of technical requirements which would allow ground personnel to turn off the satellite sensors over selected areas of the Earth coinciding with natural boundaries. Another required prior consent of the sensed nation before imagery could be gathered by the launcher nation. Thus, initial efforts to protect national sovereignty centered on the prevention or restriction of the space activity itself.

However, it soon became apparent that technical and legal restrictions were neither feasible nor desirable, and that without solving the problem of protecting the sovereign right of states to all data pertaining to their natural resources, such restrictions could interfere with international cooperation in studies of the Earth's atmosphere and oceans, in which all states have a vital interest.

Discussion then focussed on that aspect of the system considered to pose the greatest threat to national sovereignty—dissemination of the data. A consensus was reached that the space segment could be treated separately from the ground segment, and it was generally agreed that the space segment could be conducted in accordance with the freedom of exploration and use principle in the 1967 Outer Space Treaty, but the ground segment would not be covered by the Treaty. According to this view, the ground segment would be governed only by the rules of national sovereignty. Since the free and unrestricted dissemination of data, in this perspective, is not compatible with protection of national sovereignty, any space data dissemination scheme would have to be regulated to protect the sovereign right of a state over information on its natural resources, as well as the resources themselves.

In essence, data gathering was distinguished from its use. Proponents of this approach claim that treating the space and ground segments separately does not raise obstacles for the further development of the practical application of space technology, while it does allow for international regulation to prevent the misuse of data collected from space.

d. U.N. efforts to establish principles for remote sensing programs.—The United Nations has been actively debating the legal implications of remote sensing since January 1973, when a working group established by the Scientific and Technical Subcommittee of COPUOS first addressed these issues at length.[14] The subcommittee requested the views of COPUOS' Legal Subcommittee, which also began addressing these issues in 1973. Both subcommittees have worked on developing principles for operation of satellite remote sensing systems since that time.

During the 1973-74 time period, the Soviet Union, Canada, Argentina, Brazil, and France submitted proposals for formulating legal principles for remote sensing to the Legal Subcommittee. By 1975, it had become apparent that the legal issues involved in remote sensing were of increasing concern to COPUOS members, and the Legal Subcommittee allocated 1 week of its meeting to this subject. A working group was established within the subcommittee.

---

[14] This history of COPUOS' debate over remote sensing is partially based on: Gerald J. Mossinghoff and Laura D. Fuqua. "United Nations Principles on Remote Sensing: Report on Developments 1970-1980." Journal of Space Law, Fall 1980, p. 105.

The individual proposals developed earlier were, in some cases, combined, and the working group turned its attention to the three major proposals: a joint French/Soviet proposal; a joint Argentine/Brazilian proposal; and a proposal by the United States.

Since 1975, this topic has been a priority item on the agenda of the Legal Subcommittee every year, focussing on the development of draft principles. Five draft principles were developed in 1976, but by 1978 this had grown to seventeen.[15]

During its 1977 meeting, the Scientific and Technical Subcommittee made several recommendations concerning remote sensing, including the refinement of definitions, particularly of the terms "data" and "information" as they relate to remote sensing satellite systems. "Data" was redesignated "primary data" and defined to denote the raw data acquired from the satellite, and the preprocessed products derived from those data. "Information" was changed to "analyzed information" and was defined to mean the end product resulting from the process of analysis performed on primary data, combined with data and knowledge obtained from sources other than remote sensing satellites.

At the same meeting, the Soviet Union submitted a proposal to classify remote sensing data on the basis of spatial resolution: "global" data would include data with resolution of several hundred meters to several kilometers and covering distances from several hundred kilometers to 2,300–3,000 kilometers; "regional" data would have a resolution of 50–100 to 300–500 meters and covering a distance of from 180–200 to 600–800 kilometers; and "local" data would have a resolution from several meters to 30–50 meters and cover a distance of less than 150–180 kilometers. The subcommittee could not agree whether or not it was necessary to classify the data in this manner, and COPUOS and recommended that an attempt be made to provide a technical definitioni of spatial resolution and determine what aspects of data (resolution, spectral characteristics, etc.) might correspond to particular applications.

The COPUOS Secretariat, together with the Committee on Space Research [COSPAR] of the International Council of Scientific Unions, prepared such a report, which was considered at the 1978 meeting of the Scientific and Technical Subcommittee. The Subcommittee still could not agree on the need for such classifications, but noted that some governments wanted to develop different methods of distributing data based on their spatial resolution. The Soviet Union, for example, suggested that data with better than 50-meter resolution not be disseminated without permission of the sensed state because it might affect the economic and/or defense interests of the country.[16]

During 1978, the Legal Subcommittee adopted use of the definitions of "primary data" and "analyzed information" which had been developed by the Scientific and Technical Subcommittee, as well as a new definition of the "remote sensing of the Earth", but noted that no final agreement had been reached on the use of these definitions. They were added as a new draft principle, though.

---

[15] The various proposals and draft principles are reprinted in Mossinghoff and Fuqua, ibid.

[16] As noted previously, the Soviet Union and other Soviet bloc nations have signed a treaty stating that data with better than 50-meter resolution will not be distributed without prior consent of the sensed country.

A number of other new draft principles were also added during the 1978 meeting, bringing the total to seventeen. These continue to form the basis of discussions within COPUOS at the end of 1981, and are as follows (words in brackets indicate that agreement has not been reached on the wording; footnotes similarly indicate areas in disagreement).

PRINCIPLE I [17]

For the purpose of these principles with respect to remote sensing of the natural resources of the earth and its environment: [18]

(a) The term "remote sensing of the earth" means "remote sensing of the natural resources of the earth and its environment." [19]

(b) The term "primary data" means those primary data which are acquired by satellite-borne remote sensors and transmitted from a satellite either by telemetry in the form of electromagnetic singals or physically in any form such as photographic film or magnetic tape, as well as preprocessed products derived from those data which may be used for later analysis.

(c) The term "analyzed information" [20] means the end-product resulting from the analytical process performed on the primary data as defined in paragraph (b) above combined with data and/or knowledge obtained from sources other than satellite-borne remote sensors.

PRINCIPLE II

Remote sensing of the earth from outer space and international cooperation in that field [shall] [should] be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and taking into consideration, in international co-operation, the particular needs of the developing countries.

PRINCIPLE III

Remote sensing of the earth from outer space [shall] [should] be conducted in accordance with international law, including the Charter of the United Nations and the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, and the relevent instruments of ITU.

PRINCIPLE IV

1. States carrying out programmes for remote sensing of the earth from outer space [should] [shall] promote international co-operation in these programmes. To this end, sensing States [should] [shall] make available to other States opportunities for participation in these programmes. Such participation should be based in each case on equitable and mutually acceptable terms due regard being paid to principles . . .

2. In order to maximize the availability of benefits from such remote sensing data, States are encouraged to consider agreements for the establishment of shared regional facilities.

PRINCIPLE V

Remote sensing of the earth from outer space [should] [shall] promote the protection of the natural environment of the earth. To this end States participating in remote sensing [should] [shall] identify and make available information useful for the prevention of phenomena detrimental to the natural environment of the earth.

---

[17] The question of the application of these principles to international intergovernmental organizations will be considered later.

[18] The formulation "with respect to remote sensing of the natural resources of the earth and its environment" will be reviewed in light of the title to be given to the principles.

[19] This term is still subject to further discussion. In the view of some delegations, it would be necessary in the future work to further define the meaning of the words "remote sensing of the earth and its environment."

[20] The content, definition and necessity of the term "analyzed information" is still to be clarified.

PRINCIPLE VI

States participating in remote sensing of the earth from outer space [should] [shall] make available technical assistance to other interested States on mutually agreed terms.

PRINCIPLE VII

1. The United Nations and the relevant agencies within the United Nations system should promote international co-operation, including technical assistance, and play a role of co-ordination in the area of remote sensing of the earth.
2. States conducting activities in the field of remote sensing of the earth [shall] [should] notify the Secretary-General thereof, in compliance with article XI of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other celestial Bodies.

PRINCIPLE VIII

Remote sensing of the earth from outer space should promote the protection of mankind from natural disaster.[21] To this end, States which have identified primary data from remote sensing of the earth and/or analyzed information in their possession which would be useful in helping to alert States to impending natural disasters, or in assisting States to deal with natural disasters should, as promptly as possible, notify those States affected or likely to be affected of the existence and availability of such data and/or information. Such data and/or information should, upon request, be disseminated as promptly as possible.

PRINCIPLE IX [22]

Taking into account the principles II and III above, remote sensing data or information derived therefrom [shall] [should] be used by States in a manner compatible with the legitimate rights and interests of other States.[23, 24]

PRINCIPLE X

States participating in remote sensing of the earth either directly or through relevant international orgaqnization [shall] [should] be prepared to make available to the United Nations and other interested States, particularly the developing countries, upon their request, any relevant technical information involving possible operational systems which they are free to disclose.

PRINCIPLE XI

[States [shall] [should] bear international responsibility for [national] activities of remote sensing of the earth [irrespective of whether] [where] such activities are carried out by governmental [or non-governmental] entities, and [shall] [should] [guarantee that such activities will] comply with the provisions of these principles.]

PRINCIPLE XII

A sensed State [shall] [should] have timely and non-discriminatory access to primary data obtained by remote sensing of the earth from outer space, concerning its territory, on [agreed] reasonable terms and [no later than] [before] access is granted to any third State.[25,26] [[To the greatest extent feasible and practicable.] this principal shall also apply to analyzed information.]

---

[21] The meaning of this term is subject to further discussion.

[22] Should be considered in connexion with the formulation of a principle on dissemination of data or information and subject to later discussion of the terms "information" and "data."

[23] Some delegations were of the view that, for the sake of consistency it was necessary to consider this principle in light of draft principles II and III.

[24] A delegation reserved its position on removing the square brackets around the words "in a manner compatible with" and on the deletion of the words "not" and "to the detriment of."

[25] The question of from which States access to and provision of data should be obtained, needs further consideration.

[26] Subject to review in light of the discussion on access by third States.

PRINCIPLE XIII

[A State [intending to conduct] [conducting] remote sensing activities of the earth from outer space shall notify the Secretary-General of the United Nations and [upon request] the States whose territory is intended to be covered by such activities [to the fullest extent feasible and as soon as practicable] of the intended launch, [nature of the] mission, duration and coverage of such activities. The Secretary-General shall publish information thus received.]

PRINCIPLE XIV

[A State carrying out remote sensing of the earth [shall] [should] without delay consult with a State whose territory is sensed upon request of the latter in regard to such activity, [in particular dissemination of data and information,] in order to promote international co-operation, friendly relations among States and to enhance the mutual benefits to be derived from this activity.]

PRINCIPLE XV

[States carrying out remote sensing of the earth shall not, without the approval of the States whose territories are affected by these activities, disseminate or dispose of any data or information on the natural resources of these States to third States, international organizations, public or private entities.]

PRINCIPLE XVI

[Without prejudice to the principle of the freedom of exploration and use of outer space, as set forth in article I of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, remote sensing of the earth [should] [shall] be conducted with respect for the principle of full and permanent sovereignty of all States and peoples over their own wealth and natural resources [with due regard to the rights and interest of other States and their natural and juridical persons in accordance with international law] [as well as their inalienable right to dispose of their natural resources] [and of information concerning those resources.]]

PRINCIPLE XVII

[Any dispute that may arise with respect to the application of [Activities covered by] these principles [shall] [should] be resolved by prompt consultations among the parties to the dispute. Where a mutually acceptable solution cannot be found by such consultations it [shall] [should] be sought through other [established] [existing] procedures for the peaceful means of settlement of disputes mutually agreed upon by the parties concerned.][27]

By the end of 1981, no further progress had been made on reaching agreement on these principles at the United Nations.

II. APPLICATIONS EXPLORER MISSION SATELLITES

NASA has launched three Explorer-class satellites for environmental monitoring purposes (called Applications Explorer Missions). The first was the 1978 Heat Capacity Mapping Mission, followed by the Stratosperic Aerosol and Gas experiment and the Magnetic Field Satellite, both in 1979. Other satellites, both in the Explorer series and other programs (such as the Orbiting Geophysical Observatories) with related missions are discussed in volume I, chapter 9, Space Science).

A. HEAT CAPACITY MAPPING MISSION [HCMM]

The first spacecraft built to test the feasibility of measuring variations in the Earth's temperature was launched on April 26, 1978.

---

[27] Subject to review in the light of the fulls set of agreed principles and a decision on the legal nature of the principles.

The Heat Capacity Mapping Mission [HCMM], also known as Applications Explorer Mission 1, traveled in a circular, Sun-synchronous 620 kilometer (385 mile) orbit that enabled scientists to measure mid-latitude test areas of the Earth's surface first for their minimum temperatures and then for their maximum temperatures 11 hours later. The spacecraft suffered a severe degradation of its battery eight months after launch although data was returned until the satellite was deactivated on September 30, 1980.

The HCMM spacecraft weighed approximately 100 kilograms, had three-axis stabilization (to an accuracy of 2–3°), and used solar panels coupled with storage batteries for power supply. It carried a two-channel scanning radiometer which could acquire images in the visible (0.5–1.1 microns) and near infrared (10.5–12.5 microns) bands of the spectrum. Resolution for the visible channel was 500 meters and for the infrared channel, 600 meters, with a temperature resolution of 0.5 degrees. The spacecraft acquired data along a 700 kilometer wide swath.

The mission was designed to allow scientists to determine the feasibility of using day-night thermal data for discriminating between various rock types, locating mineral resources, measuring and monitoring surface soil moisture changes, measuring plant canopy temperatures at frequent intervals to determine transpiration of water and plant stress, measuring urban heat islands, mapping surface temperature changes on land and water, and deriving information from snow fields for water runoff predictions.

The HCMM spacecraft could measure temperature changes associated with solar heating during the daytime and radioactive cooling at night. This temperature difference is related to the properties of the surface layer being measured (approximately 5–10 centimeters deep). For example, some types of rocks (such as shale) have a wide day-night temperature difference, while others (such as quartz) do not.

The satellite made 5,981 data passes during its lifetime. Test sites for HCMM had been located in various parts of the United States, Western Europe, and Australia, and 12 American and 12 foreign investigators participated in the original program in five different discipline areas: agriculture/soil moisture, climatology, geology, hydrology, and oceanography.

HCMM data has been used to discriminate soils with different porosity and moisture content, and for identifying subsurface structural features in the Earth's crust which are blanketed by thin layers of sand and gravel. In addition, data has been used to develop an analysis of urban heat islands and to differentiate rock with similar albedos.

Data from HCMM was correlated with that from other satellites, including Landsat and Seasat.[28] One finding using HCMM and Seasat data was that such a combination could provide data about crustal structure that could not be obtained from visible imagery alone.

---

[28] For example see: "Space-Derived Data Combined." Aviation Week and Space Technology, Feb. 8, 1982. pp. 38–41.

As described in NASA's post-launch report,[29] some of the major results from the HCMM program include: detection of major thermal lineaments in Wyoming and Arizona, which have no apparent expression in the visible or near-infrared imagery (such as that obtained by Landsat), which may have a controlling influence on the regional emplacement of mineral deposits; determination of surface soil temperature and soil water content in agricultural regions of the U.S. Midwest; discovery of an empirical relationship between moisture availability and antecedent rainfall in vegetated regions; and observations which have led to a reinterpretation of the "heat island" effect in metropolitan areas which is now attributed to low moisture availability rather than the thermal inertia of buildings, roads, etc.

Although NASA judged the program as a whole to have been a success, it identified a significant weakness in the program as the inability of Goddard Space Flight Center's ground data processing facility to accommodate the image processing needs of HCMM along with Landsat and the Nimbus 6 and 7 satellites in a timely manner. A collection of the best available HCMM imagery obtained over the United States is being reduced to digital format and will be made available to qualified investigators through Goddard's National Space Science Data Center.

Although there is no specific follow-on program for HCMM, many of the experiments that will be conducted using the thematic mapper on Landsats D and D' are related to the same types of investigations.

B. Stratospheric Aerosol and Gas Experiment [SAGE]

On February 18, 1979, NASA launched the Stratospheric Aerosol and Gas Experiment [SAGE], also known as Applications Explorer Mission 2. The satellite was the first to make extensive vertical measurements of aerosols in the stratosphere, the area which extends from about 9 to 40 kilometers above the Earth. The satellite was still functioning at the end of 1981, although it had experienced a severe battery voltage loss.

During the 1970's, concerns developed that industrial and aviation activities would lead to aerosols and gases getting trapped in the stratosphere, and that the release of chlorofluoromethanes [CFM's] would destroy the ozone layer (models had predicted that if CFM releases continued at their 1975 level, 8–30 percent of the ozone would be destroyed).

SAGE was therefore designed to obtain global data on aerosols, ozone, nitrogen dioxide, and molecular extinction in the stratosphere. To accomplish this goal, the satellite carries a four channel radiometer which measures solar intensity in four bands from near infrared to blue: 0.385 microns, 0.45 microns, 0.6 microns, and 1.0 microns. As the spacecraft orbits the Earth, it enters and emerges from Earth's shadow 15 times each day, for a total of 30 sunrises and sunsets. Each time, it looks at the Sun through the Earth's atmosphere and measures the attenuated solar intensity. Ozone concentrations can be measured from 9 to 46 kilometers altitude, aerosols from the cloud tops to 35 kilometers, nitrogen dioxide from 25 to 40 kilometers, and molecular extenction from 15 to 40 kilometers.

---

[29] U.S. National Aeronautics and Space Administration. "Post Launch Report on the Heat Capacity Mapping Mission." Washington, NASA, Oct. 8, 1982. Post-launch mission operation report No. E-651-78-01.

Findings from SAGE are checked against ground truth data acquired using balloons and rockets launched in the United States, Japan, and Europe. To date, these checks have confirmed the accuracy of the SAGE data. SAGE complements the Stratospheric Aerosol Measurement experiment carried on the Nimbus 7 satellite (see chapter 4).

The satellite weighs 147 kilograms and uses solar panels coupled with batteries (for storage) for power supply. The satellite was placed in a 640 x 550 kilometer orbit at 55° inclination. Four months after launch, a severe loss of power in the battery developed, as had happened with the HCMM mission (the batteries for both had been purchased at the same time from the same manufacturer's lot).

On October 21, 1982, NASA published a post-launch report on SAGE, declaring the mission a success and outlining some of its findings.[30] According to that report, SAGE had obtained over 12,000 measurement events from 78° south to 78° north latitude and had shown its capability to accurately measure verticle profiles of aerosols and ozone from space. The satellite had detected and tracked five volcanic eruptions (La Soufriere in April 1979, Sierra Negra in November 1979, Mount St. Helens in May 1980, Ulawun in October 1980, and Aloid in May 1981). SAGE provided the first global aersol data set ever obtained, and for the first time an accurate measurement of the global background stratospheric aerosol mass loading and its seasonal variation were determined. Data from SAGE showed an equatorial mid-to-low stratospheric source region for aerosols and confirmed the mid-stratospheric equatorial source for ozone.

The SAGE mission also provided the first vertical profile data on nitrogen dioxide extending above its mixing ratio peak; only about 15 profiles had been available previously. SAGE detected polar stratospheric clouds (important for studies of the earth's radiation budget and water vapor sink), and the occurrence of sudden warnings of the stratosphere and the associated rapid transport of ozone and nitrogen dioxide, which will aid in understanding atmospheric dynamics.

C. Magnetic Field Satellite [Magsat]

1. Introduction

The first satellite specifically designed to measure Earth's magnetic field and crustal anomalies was launched on October 30, 1979. Called Magsat, for Magnetic Field Satellite, it was the third of the Applications Explorer Satellite series, and provided data until moments before it burned up as it reentered the atmosphere on June 12, 1980.

---

[30] "Post Launch Report on Stratospheric Aerosol and Gas Experiment (SAGE)." Post launch mission operation report No. E-659-79-01. Oct. 20, 1981.

Satellite measurements of the geomagnetic field were first made using the Soviet spacecraft, Sputnik 3, in May 1958. The six U.S. Orbiting Geophysical Observatories (see volume I, chapter 9) launched between 1965 and 1971 also provided data of the field magnitude over an altitude ranging from 400 to 1,500 kilometers. These provided only scalar measurements, though. The addition of a vector magnetometer on Magsat, instead of only a scalar instrument, coupled with its lower orbit, allowed the acquisition of data superior to that of previous satellites.

2. The Earth's magnetic crust

The magnetic field of the Earth's crust is much weaker than the planet's more familiar main magnetic field that is associated with compasses and the magnetic pole. The average strength of this crustal magnetic field is approximately 50,000 gammas, roughly equal to a toy horseshore magnet, and the variations from one place to another average 10 to 12 gammas.[31]

The magnetic crust extends from the Earth's surface down to an irregular boundary some 16 to 48 kilometers beneath the surface. Three classes of phenomena have been identified with variations in this crust.

First, in area of young volcanic activity where upwelling heat is great, rocks become so heated that they lose magnetism at the base of the magnetic layer. This results in a comparatively thin magnetic crust and a region of relatively low magnetism. Maps of such areas can be used to locate geothermal resources.

Another phenomenon relates to the structure of underlying rock, for example in the Eastern United States where magnetic intensities rise from coastal plains to highs in the Appalachians. Geologic mapping of such areas can benefit from a knowledge of magnetic anomolies.

The third phenomenon concerns the densities of subsurface rock in that high magnetic anomolies are sometimes associated with deposits of buried ores, particularly iron. Aircraft surveys are often too close to the surface to detect these anomolies because the sensors become confused by the magnetism of surface rocks. Using satellites, whole continents can be studied at one time, providing better data.

3. The Magsat Mission

The objectives of the Magsat mission were to develop an accurate, up-to-date quantitative description of the Earth's magnetic field, provide data and a worldwide magnetic-field model suitable for the U.S. geological Survey update and refinement of world and regional magnetic charts, and compile a global two-dimensional (scalar and vector) crustal magnetic anomaly map with a spatial resolution better than 350 kilometers. The mission was successful in meeting all these objectives.[32]

---

[31] Information on the Earth's magnetic crust and associated anomalies was excerpted from: John Noble Wilford. "Satellite to Map Earth's Magnetism." New York Times, Oct. 30, 1979. p. C1.

[32] "Magnetic field satellite [Magsat] Post Launch Report #2." NASA postlaunch mission operation report No. E-662-80-01. Oct. 20, 1980.

Magsat carried two magnetometers, one for measuring the magnitude of the local magnetic field around the satellite [scalar], and the other for giving information about the field's direction [vector]. Both instruments were placed at the end of a 6 meter long boom to keep them away from the electronics in the satellite itself. Magsat was placed into a sun-synchronous, polar orbit with an apogee of 578 kilometers and a perigee of 352 kilometers. The oribital path of the satellite covered the entire globe once every ten days. The spacecraft weighed 183 kilograms, was three-axis stabilized to an accuracy of 5 degrees, and utilized solar panels for power supply. Tape recorders onboard the satellite could store data for later relay to a ground tracking station.

NASA selected 32 proposals for investigations using Magsat data—19 from the United States and 13 from foreign scientists (from Australia, Brazil, Canada, France, India, Italy, Japan, and the United Kingdom) in six disciplines: geophysics, geology, field modeling, marine studies, magnetosphere/ionosphere, and core/mantle studies.[33]

The data from the mission was three times better than the design goal and had 3 gamma accuracy in the scalar field and 6 gamma accuracy in each component of the vector field.[34] Magsat data confirmed the decreasing intensity of Earth's main magnetic field at a rate of 0.09 percent annually, meaning that a reversal of the planet's north and south poles may occur in 1,200 years. Scientists speculate that such reversals occur randomly at intervals varying between 50,000 and 1 million years; the last occurred 700,000 years ago.[35]

The data has also been used to identify crustal magnetic anomalies that may indicate the presence of certain minerals. The minerals exploration industry uses such models for selecting area for further ground-based investigation.

NASA was able to provide magnetic field model data to users within 2 months and provided a world anomaly map in 13 months.[36]

---

[33] "Experiments Selected for Magnetic Field Satellite." NASA press release 79-103. Aug. 8, 1979.

[34] U.S. Congress. House. Committee on Science and Technology. Subcommittee on Space Science and Applications. 1982 NASA authorization (program review). 96th Congress, 2d session, Sept. 16, 17, 18, 1980. Washington, U.S. Government Printing Office, 1980. p. 313.

[35] "Magsat Provides Most Accurate Model on Earth's Geomagnetic Field." Goddard News, July 7, 1980. p. 4.

[36] U.S. Congress. House. Committee on Science and Technology. Subcommittee on Space Science and Applications. 1981 NASA authorization. 97th Congress, 1st session, Mar. 12, 17, 18, 19, 20, 21, 23 and 24, 1981. Washington, U.S. Government Printing Office, 1981. p. 2395.

CHAPTER SIX

OCEAN SENSING SATELLITES

The ocean acts as a planet-wide reservoir for the storage and dissipation of solar energy through a variety of natural processes, including oceanic circulation, generation and propagation of wind waves, evaporation, and generation of major storms. Such heat exchanges between ocean and atmosphere result in large scale transport of energy on a global scale and have a major influence on weather and climate. For example, it is estimated that as much as 40 percent of all the heat in the atmosphere could derive from the latent heat released through condensation of water vapor that enters the atmosphere by way of evaporation from the ocean. Numerical models are considered by many atmospheric scientists to be the chief scientific tool for predicting future states of the atmosphere, and satellite observations have come to play an increasingly important role in the design, verification, and calibration of large-scale atmospheric/oceanic circulation models.

In addition, improved oceanographic data has many applications in the commercial, industrial, and academic communities. For example, sea temperature is a parameter of considerable importance in air/sea interaction, since it is a manifestation of the receipt, absorption and conversion of solar radiation into heat. The difference between active and inactive hurricane seasons may be due to water temperatures in hurricane gestation areas just 2 to 3 degrees centigrade different from the average. Atmosphere and ocean can interact in this and a number of other complex ways, and these interactions may be among the more important influences on the Earth's weather and climate. The transfer of energy between these two media helps to govern weather and climate conditions, as well as climatic variability, not only over the ocean, but over land masses as well, by influencing the course of such features as the jet stream.

Additionally, maps of sea surface temperature and sea surface temperature anomalies are useful in understanding the dynamics of ocean currents. Open-ocean fish such as tuna tend to swim along the lines of constant temperature at certain times in their excursions, so ocean temperature data may be helpful to commercial fishing interests in locating schools of fish.

The temperature of the ocean's surface can be mapped in cloud-free areas of the ocean by infrared satellite sensors, but temperatures over clouded areas must be directly measured from ships or recorded and relayed telemetrically by data buoys if only infrared sensors are available. Space-based microwave sensors, on the other hand, can provide an all-weather sea surface temperature measurement capability.

Surface wind data is another example of potential commercial applications of satellite derived ocean data. Satellite wind surface observations could provide data equivalent to that obtained through 20,000 ship reports a day, an order of magnitude larger than that currently provided by surface vessels. In addition, satellite data could be nearly uniformly distributed over the global oceans, thus filling the major gaps in the meteorological grid patterns which result from the fact that "ships of opportunity" tend to traffic the North Atlantic and North Pacific shipping lanes. Using wind data from the spacecraft in conjunction with observations recorded aboard ships, on buoys, and at island stations, it might be possible to better define the vector surface wind field throughout the planetary boundary layer every 24 hours.

Better definition of the surface wind field over the oceans would also be a large step forward in ocean wave forecasting. Together with other data, it should facilitate development of an advanced, computerized global wave forecast model whose potential monetary value to marine interests is significant.

The military is also interested in obtaining data about the ocean for a number of applications, including U.S. fleet mobility, and antisubmarine warfare.

NASA has launched satellites in the past which carried ocean sensors (especially in the Nimbus and GEOS programs, see chapters 4 and 7 respectively), but the first satellite devoted exclusively to ocean sensing was Seasat, launched in 1978. Unfortunately, an electrical system malfunction caused the satellite to cease operating after 106 days in orbit. A program designed to develop a limited operational ocean sensing capability for both the civil and military sectors, called the National Oceanic Satellite System [NOSS], was planned by NASA, the Department of Commerce's National Oceanic and Atmospheric Administration [NOAA], and the Navy, but the program was canceled by the Reagan administration in 1981 because of budget constraints. The Navy may propose a replacement program, called ROSS (for Remote Ocean Sensing System) in later years.

I. SEASAT

A. INTRODUCTION

In view of the influence of the world ocean on global atmosphere circulation patterns, a need was perceived for a satellite that could monitor key features of the many processes involved in the interacting air, sea, and ice components of the climatic system. Seasat was a "proof-of-concept" mission, designed to determine if microwave instruments scanning the oceans from space could provide useful scientific data for oceanographers, meteorologists, and commercial sea interests.[1] The objectives of the Seasat program were fourfold:

To demonstrate the scientific feasibility of microwave measurement of oceanographic data from space;

---

[1] Seasat is sometimes referred to as Seasat A or Seasat 1. Preliminary studies of a Seasat B were conducted by NASA, but the program was later dropped in favor of NOSS.

To provide data for user applications to enable users to determine the utility of the system;

To determine the features for a possible follow-on operational system; and

To demonstrate the economic and social benefits of satellite data.

Launched on June 26, 1978, Seasat operated for 106 days before an electrical malfunction caused it to fail in orbit.

B. SATELLITE CAPABILITIES

Seasat was the first satellite to use a variety of microwave instruments. The sensors formed a set of integrated, interactive, and mutually supporting devices whose simultaneous use provided total information which was greater than the sum of the individual parts. The selection of instruments was made in order to determine ocean surface conditions in accordance with user data requirements set forth during NASA-sponsored meetings in early 1973. The package aboard Seasat was comprised of the following sensors:

(1) *Microwave scatterometer.*—For measuring fine-scale ocean surface roughness caused by surface winds by Bragg scattering from wind-generated capillary waves; measurements can be converted directly into wind velocity and direction.

(2) *Scanning multichannel microwave radiometer.*—For measuring sea surface temperature, estimating higher wind speeds and detecting atmospheric moisture; it simultaneously senses the microwave energy emitted by and reflected from the ocean, ice, and atmosphere; several frequencies were used in order to separate out the various contributions to the signal from these sources; wind speed instrument sensed the increase in emitted microwave energy due to roughness, foam, and streaks on the ocean caused when higher wind speeds create wave breaking and whitecaps.

(3) *Synthetic aperture radar.*—Provided all-weather high-resolution images of ocean waves, ice fields, icebergs, ice heads (linear openings in ice through which ships may navigate), coastal conditions, land, and snow cover.

(4) *Radar altimeter.*—For monitoring average wave height and "significant wave height" (the average of the highest one third of all waves) and the altitude of the spacecraft above the ocean to a precision of 10 centimeters; altitude when added to accurate orbit determination may be used to provide information on sea surface topographic features that relate to ocean tides, storm surges and currents, and the shape the oceans assume under the influence of gravity.

(5) *Visible and infrared radiometer.*—For providing images of thermal infrared emission from ocean, coastal, and atmospheric features to aid in interpreting the measurements from the four microwave instruments.

Seasat data from these instruments was corroborated by measurements from low flying aircraft, ships and instrumented buoys. Although Seasat data were limited to surface and near-surface phenomena, these data are very useful since the interaction between ocean and atmosphere largely takes place in the few tens of meters above and below the sea-air interface. In addition, satellite data can be supplemented with conventionally derived subsurface measuements to obtain a three-demensional view of the ocean.

C. DATA GATHERING AND DISSEMINATION

All of the instruments, except the imaging radar, were operated continuously during most of the mission to provide global coverage. Data were stored onboard the satellite if it was out of sight of one of the five active NASA tracking stations, and later relayed back to Earth. The imaging radar operated in real time, and only over appropriate high-data-rate ground stations.

Data were forwarded from the various receiving stations to NASA's Goddard Space Flight Center where data sets were converted into geophysical quantities (e.g., wind speed, wave height, etc.) and disseminated to research scientists. Data were provided to NOAA for its use and subsequent archiving and distribution. There was one quasi-operational experiment in which data were provided in near real time to the Navy's Fleet Numerical Weather Central [FNWC][2] where it was processed and used in its twice daily global weather and sea state predictions. The FNWC output products were also provided to NOAA for use and further distribution.

D. COST AND USER PARTICIPATION

Seasat was estimated to cost $58.2 million in 1973 when the program began, but the actual cost rose to $74.7 million, primarily because of inflation and changing user requirements. In December 1973, NASA established a cost ceiling for Seasat in the expectation that the previously defined user requirements of a five instrument payload could be adequately met for $58.2 million (including launch). By May 1974, NASA determined that the cost of the five-sensor satellite would exceed the cost ceiling, due to better definition of instrument specifications and inflation. Thus, in the fall of 1974, NASA, in conjunction with the potential Seasat users, changed the payload configuration and eliminated the scanning multifrequency microwave radiometer. When the user community had second thoughts and objected to the removal of this instrument, NASA decided to raise the cost ceiling on the project rather than fly hardware which the users considered inadequate.

---

[2] Now the Fleet Numerical Oceanography Center.

TABLE 6-1

USER ORGANIZATIONS THAT PARTICIPATED IN THE DEVELOPMENT OF SEASAT

Government

- Department of Commerce
  - National Oceanic and Atmospheric Administration
    - National Weather Service
    - National Environmental Satellite Service
    - National Ocean Survey/NOAA Data Buoy Center
    - Environmental Research Laboratories
    - National Marine Fisheries Service
  - Maritime Administration
- Department of Defense
  - Office of Naval Research
  - Naval Research Laboratory
  - Naval Weapons Laboratory
  - Naval Weather Service Command
  - Naval Oceanographic Office
  - Defense Mapping Agency
  - Army Corps of Engineers
- Department of the Interior
  - Geological Survey
- Department of Transportation
  - Coast Guard
- Energy Research and Development Administration
- Environmental Protection Agency
- National Science Foundation
- National Aeronautics and Space Administration

Institutions

- National Academy of Sciences
- National Academy of Engineering
- Smithsonian Astrophysical Observatory
- Woods Hole Oceanographic Institution
- Scripps Institution of Oceanography/University of California
- University Institute of Ocenography/City University of New York
- Batelle Institute

Private Sector

- American Institute of Merchant Shipping
- American Petroleum Institute
- Sea Use Council

Prepared by Lani Raleigh, Congressional Research Service.

The user community was involved in the Seasat program from its inception to ensure that it would be designed for their needs. Table 6-1 provides a list of the users involved in Seasat development. By initiating a wide range of commercial and government agency involvement in Seasat from the the start of spacecraft operations, NASA hoped to avoid being in the position of forcing the development of an operational system. Rather, the expectation was that the operational system would be developed by the user community. NASA's principal interest in the Seasat program was in development and system validation, while NOAA accepted responsibility for the majority of research and applications work conducted from Seasat. Thus, joint solicitations for Seasat investigations were issued by NASA, NOAA, the Department of Defense [DOD], the U.S. Coast Guard, the National Science Foundation, and the U.S. Geological Survey. This represented a significant departure from past procedure in which NASA selected and managed spacecraft principal investigators.[3]

In addition, NASA formulated an industrial users program to determine the economic benefits to be derived from Seasat data. Under the plan, the users were to support the cost of the research program at their field sites, while NASA's primary obligation to the program was to obtain the Seasat data and provide it to the user in a suitable format. Some of the key users in the industrial demonstration program were to be:

Oceanroutes, Inc.—A company which provides worldwide weather routing services to over 900 ships per month and was to undertake two major investigations involving weather routing and use of Seasat data in offshore oil platform operations in the Gulf of Alaska; and an assessment of the effect of Seasat data in improving ship routing through optimum ocean conditions as well as sea surface temperature route predictions using Seasat. These data are important in oil tanker operations where oil temperatures determine how quickly loaded tankers can be offloaded for more trips.

Sun Shipbuilding and Drydock Co.—Synthetic aperture radar data taken over the Beaufort and Chukchi Seas were to be used in monthly assessments of structural changes in ice pressure ridges and the ability to provide navigation paths through the areas where ice pressures ridges would have the least effect. Sun Shipbuilding, which designs and builds icebreaking tankers, was to assess the value of Seasat data in a simulation model for determining the optimum designs for icebreaking tankers operating in the Beaufort and Chukchi seas north of Alaska.

Marine Fisheries Experiment.—Several commercial fishing interests were to determine the utility of using Seasat sea surface temperature as an aid to fishing. Fish such as tuna and salmon thrive in water of specific temperatures. In addition, winds cause upwelling of the water, bringing to the surfaces nutrients on which the fish live. Seasat was to be evaluated for its ability to direct vessels to promising areas more quickly, compared to the service currently provided by NOAA polar weather satellites.

Alaskan Crab Fisheries Experiment.—Crab fishing in Alaska is very dependent upon accurate weather and sea state forecasts. Seasat data was to be evaluated to determine its impact on facilitating crab fishing and preventing losses in equipment.

Offshore Oil, Gas, and Mining Uses.—Construction, installation, and operation of offshore oil and gas platforms is very dependent upon the weather. Seasat data were to be used to determine how space-derived information can aid operations and save costs. The offshore operations were to provide ground truth data to aid in evaluation of Seasat capabilities. Participants were to include the Arctic Petroleum Operations Assn., the East Coast Petroleum Operators Assn., the American Gas Assn. Pipline Research Committee, Continental Oil Company, the Getty Oil Company, Union Oil

---

[3] Covault, Craig. "Seasat User Program Organized." Aviation Week and Space Technology, Mar. 14, 1977. pp. 14-16.

Company, Deepsea Ventures, Kennecott Exploration, Inc., and the Arctic Research Committee.

As result of the failure of Seasat in orbit, the studies originally envisioned could not be carried out. Several studies were made of the utility of Seasat data, though, and these are discussed in section G.

E. INTERNATIONAL PARTICIPATION

On September 19, 1978, NASA and the Canadian Department of Energy, Mines and Resources, signed an agreement for the development of a digital method of processing synthetic aperture radar [SAR] data for enhanced iceberg detection capability. According to the terms of the agreement, the Canadians were to equip a station at Shoe Cove, Newfoundland, and provide NASA with a duplicate set of processing equipment for its Fairbanks, Alaska, station. In return, the SAR was to be operated while the spacecraft was in view of the Newfoundland station and the Canadians were to exchange their data with SAR data received at Fairbanks. Initially, the U.S. Department of Defense [DOD] had objected to international participation in the Seasat program. DOD had been particularly concerned about distribution of the radar altimeter and the high resolution synthetic aperture radar data. In June 1977 President Carter resolved the issue in favor of international participation.

The Europeans were also interested in experimentation with Seasat data. The European Association of Remote-Sensing Laboratories, a cooperative body set up under the auspices of the Parlimentary Assembly of the Council of Europe, with support from the Commission of European Communities and the European Space Agency, drafted a program for the use of Seasat data in studies of the North Sea and the North Atlantic Ocean in early 1978.

F. SPACECRAFT FAILURE

On October 9, 1978, Seasat stopped transmitting data after satisfactorily operating in orbit for 106 days. To identify the nature and cause of this failure, NASA established a Seasat Mission Failure Investigation Board on October 16, 1978. The Board initiated its investigation on October 23.

In its report, the Board concluded that the spacecraft failure was the result of a loss of electrical power in the Agena bus that was used as a part of the spacecraft. This power loss was caused by a massive and progressive short circuit in one of the slip ring assemblies that was used to connect the rotating solar arays into the power subsystem. According to the Board, the wiring arrangement, together with the congested nature of the design itself, made the Seasat slip ring assembly a unique, first-of-a-kind component that was particularly prone to short circuits. The possibility of this type of slip ring failure was known to other projects within the contractor's organization at least as early as the summer of 1977. Thus, the Board stated that the Seasat organization's lack of awareness of such potential failure modes was due to a breakdown in communication within the contractor's organization.

In addition to the communications breakdown, the Board asserted that the failure to give the slip ring assembly the attention it deserved could be traced to an underlying program policy and a pervasive view that Seasat's Agena bus was a standard, well proven piece of equipment that had been used on other programs. However, three major subsystems—the electrical power subsystems, the attitude control subsystem, and the data subsystem—were substantially modified for use on Seasat's Agena bus. The view that the bus was standard equipment led to a program policy in which testing, documentation, and government oversight were minimized, and project management concentrated on the sensors, sensor integration, and data management system to the near exclusion of bus subsystems. Thus, the Board discovered, important component failures were not reported to project management, a test was waived without proper approval, and compliance with specifications was weak.

The Board concluded that:

> The advantages of using standard, well proven equipment in terms of both cost and mission are well recognized. But the experience of Seasat illustrates the risks that are associated with the use of equipment that is classified as "standard" or "flight proven". The uncritical acceptance of such classification by the Seasat engineering staff submerged important differences in both design and application from previously used equipment. It is therefore important * * * to fully evaluate the heritage of previously used equipment * * * and identify, component by component * * * those that are truly "standard" and those that are not. One should assume that each space vehicle is unique until proven otherwise * * * The policy of limited penetration into Seasat's Agena bus by the Government was appropriate, but a limited penetration must be a selective penetration and not a reduced effort everywhere.[4]

G. MISSION EVALUATION

Seasat's synthetic aperture radar completed some 300 data-gathering passes during which it collected about 60 hours of data including images of sea ice, waves, coastal conditions and various land forms. The spacecraft's scatterometer (sea surface wind speeds) and scanning multi-frequency microwave radiometer (sea surface temperature and wind speed) collected data for 99 days. Seasat's altimeter and visual and infrared radiometer returned data for 70 and 52 days respectively.

---

[4] U.S. National Aeronautics and Space Administration. Report of the Seasat Failure Review Board. Washington, D.C., U.S. Government Printing Office, Dec. 21, 1978, pp. 111, 10–1.

TABLE 6-2

CASE STUDIES OF UTILITY OF SEASAT DATA BY TITLE AND PARTICIPATING ORGANIZATIONS

Case Study Title	Participating Organizations
Beaufort Sea, Oil, Gas, and Arctic Operations	Esso Resources, Ltd., Gulf Oil of Canada
Labrador Sea Oil, Gas, and Sea Ice	Esso Resources, Ltd., Petro-Canada
Gulf of Mexico Pipelines	American Gas Association
U.S. East Coast Offshore Oil and Gas	Conoco, Inc.
Worldwide Offshore Drilling and Production Operations	Getty Oil Co.
East Pacific Ocean Mining	Deepsea Ventures, Inc., Kennecott Exploration, Inc., and Lockheed Ocean Laboratory
Bering Sea Ice Project	Members of Alaska Oil and Gas Association (Conducted by Oceanographic Services, Inc.)
North Sea Oil and Gas	Union Oil Co.
Marine Environmental Forecasting in the Gulf of Alaska	Oceanroutes, Inc.
Off-Shore Oil and Gas Operations — Four Ocean Areas	Ocean Data Systems, Inc.
Optimum Ship Routing	Oceanroutes, Inc.
Tropical and Temperature Tuna Fisheries	National Marine Fisheries Service, Southwest Fisheries Laboratory
Improved Real-Time Weather Forecasting	Atmospheric Environmental Service (Canada)

Source: U.S. National Aeronautics and Space Administration. Jet Propulsion Laboratory. Seasat Data Utilization Project: Final Report. Pasadena, California, NASA/JPL, Sept. 30, 1981. p. 36-37.

In February 1981, NASA's Jet Propulsion Laboratory (JPL) issued its final report on the utility of Seasat data to ocean industries based on case studies using Seasat data performed by 16 commercial organizations and Government organizations that support ocean commerce (see Table 6–2).[5] According to JPL, results of the case studies "support the potential usefulness of satellite measurements of the oceans in four major areas of commercial applications" and "provide dramatic evidence of the importance of improved weather and ocean condition forecasts to these operations, and the opportunities for cost savings through the use of these data."

The four areas of commercial applications were identified as follows:

1. Marine weather and ocean condition forecasts

According to the JPL study, case studies of the utility of Seasat data in this area showed that "the Seasat wind and wave data represent a very significant improvement over conventional observation data for oceans in both the northern and southern hemispheres."

2. Offshore resource exploration and development

In the area of offshore oil and gas exploration, JPL results showed two applications for which Seasat data were useful: establishing a historical or climatological data base of wind and wave data, especially in frontier areas of interest to oil and gas companies where such data area not currently available; and improved forecasts for planning and scheduling.

JPL also reported that Seasat data could be useful to companies engaged in offshore mining, particularly in the region of the equatorial Pacific extending from the coast of Mexico to the vicinity of Hawaii. The area is off major shipping lanes, and data is therefore sparse about the weather (which can be affected by hurricanes during part of the year).

3. Commercial fishing

Preliminary results of a JPL-sponsored case study on commercial fishing indicated a strong correlation between certain types of ocean and meteorological conditions and fish catch.

4. Marine transportation

This case study showed that improved analysis and forecasts made possible using Seasat data could further improve ship routing, which could result in savings in operating costs and reducing losses from cargo damage and personnel injuries. According to the study, savings in operating costs for vessels operating in the Atlantic, North Pacific, and Indian Oceans could be between $1 million and $3 million per year for selected routed vessels.

---

[5] U.S. National Aeronautics and Space Administration. Jet Propulsion Laboratory. "An Evaluation of the Utility of Seasat Data to Ocean Industries." 3 vols. Pasadena, Calif., NASA/JPL, Feb. 2, 1981. Also "Seasat Data Utilization Project: Final Report." Sept. 30, 1981.

II. NATIONAL OCEANIC SATELLITE SYSTEM (NOSS)

A. INTRODUCTION

The National Oceanic Satellite System (NOSS) was developed as a limited operational demonstration program following the experimental Seasat "proof of concept" program. Plans for NOSS began during Seasat development, and funding for NOSS was initiated in 1980 (fiscal year 1981). Budget constraints led the Reagan administration to cancel NOSS in 1981 (fiscal year 1982).

B. PROGRAM PLAN

In 1976, while the development of Seasat was underway, follow-on studies for a limited operational demonstration program were initiated by NASA, NOAA, and the Navy. In late 1977 and early 1978, when the Navy and NOAA had assessed and determined priorities for their requirements for an operational system, it became apparent that the requirements and the priority assigned to them by the two agencies were very similar. As a result NASA, NOAA, and the Navy decided to examine a joint program to meet both civil and military needs. (These requirements are shown in table 6-3.)

TABLE 6-3

INTERAGENCY NOSS MEASUREMENT REQUIREMENTS

Parameter	Accuracy	Resolution	Frequency	Delay
Wind				
Speed	2 m/s	25 km	6 h	3 h
Direction	10 deg	50 km	6 h	3 h
Sea Surface Temperature				
Global	1.0 C	25 km	3 days	12 h
Local	0.5 C	10 km	1 day	12 h
Waves (Sea State)				
Significant wave height	0.3 m	25 km	3 h	3 h
Amplitude components	0.7 m	25 km	3 h	3 h
Wavelength components	10%	25 km	3 h	3 h
Direction	10 deg	25 km	3 h	3 h
Ice				
Cover	15%	20 km	3 days	12 h
Thickness	2 m	50 km	3 days	12 h
Age	New, 1st yr., multi-yr.	20 km	3 days	12 h
Sheet height	0.5 -m change	10 km	1 year	30 days
Bergs	+2 km of true location	0.1 km	2 days	12 h
Water Mass Definition				
Chlorophyll	Within factor of 2	0.4 km	2 days	8 h
Turbidity	Lo, med, hi	0.4 km	1 day	10 h
Horizontal Surface Currents				
Speed	5 cm/s	20 km	1 day	1 day
Direction	10 deg	20 km	1 day	1 day

Source: Jet Propulsion Laboratory. National Oceanic Satellite System: Definition Phase Final Report. Vol. II: Requirements and Rationale. JPL publication 624-12. June 1978. p. I-4.

By early 1978, specific recommendations were developed by the three agencies based on Seasat technology.[6] The space segment would consist of two satellites carrying the following sensors: a large antenna multichannel microwave radiometer (a larger version of the scanning multichannel microwave radiometer flown on Seasat and Nimbus 7); a coastal zone color scanner (an improved version of a similar instrument flown on Nimbus 7); an altimeter very similar to the one flown on Seasat; a scatterometer (an improved version of the one flown on Seasat); and a synthetic aperture radar. The plan to fly a synthetic aperture radar was dropped in the fall of 1978 because of cost problems and concerns that it was too experimental for a quasi-operational program. NOSS would have allowed 25 percent of the payload weight to be devoted to research experiments. The satellites would have been put in near-polar, sun-synchronous orbits at 87° inclination and a 700 kilometer altitude. The design life for the satellites was 3 years; with a total operational period of 5 years.

The ground segment of the system would provide near real-time availability of data to users, a feature not included in the Seasat program. The ground system was designed to have the following components: a primary processing facility (PPF) for acquiring and processing raw data from the satellite for the primary users (Navy and NOAA); a system control center which would function as the nerve center for all NOSS operations; a spacecraft operations control center for continuous monitoring and control of the satellites; a communication system using domestic communication satellites for transmitting NOSS data from the PPF to the primary user processing centers; and a data archive. The NOAA primary processing center is located in Suitland, Md., while the Navy's is located at the Fleet Numerical Oceanography Center in Monterey, Calif.

1. Responsibilities of the three agencies

On November 25, 1980, NASA, the Department of Commerce (DOC, for NOAA), and the Department of Defense (DOD, for Navy), signed a memorandum of understanding (MOU) concerning the development of NOSS. Under the MOU, NASA would have responsibility for system acquisition, implementation, test, launch, and initial checkout of the space segment, and would address development of new and advanced technology and operational instruments, software and spacecraft systems. NASA would also interface with academic institutions and research advisory bodies such as the National Academy of Sciences. NOAA and the Navy would be the primary users. NOAA would address specifically the operational support for oceanic data in the civil community (government and nongovernment), while Navy would address specifically the oceanographic support to all military users. After an initial checkout period of approximately 1 year, the ground segment would become the responsibility of NOAA and Navy.

---

[6] National Aeronautics and Space Administration. Jet Propulsion Laboratory. "National Oceanic Satellite System: Definition Phase Final Report." 3 vols. Pasadena, Calif., NASA/JPL, June 1978. Report 624-12.

The MOU established a program management scenario including three levels of activity. At the top level, the Steering Committee (comprised of the NASA Associate Administrator for Space and Terrestrial Applications, the NOAA Assistant Administrator for Satellites, and the Director of the Naval Oceanography Division) would conduct policy review and provide overall guidance. The next level was the Program Management Team which would implement the policy decisions, define the mission, and monitor project performance, costs, and schedules, and serve as the primary interface between the three agencies. The third level, the Project Management Office, would carry out the project as directed by the Program Management Team.

According to the MOU, costs for NOSS would be shared as follows: (1) all costs for the design, development, fabrication, test, and launch of the first spacecraft (including payload) would be shared equally by DOD and NASA; (2) all costs for the fabrication, test, and launch of subsequent spacecraft (including payload) would be shared equally by DOD and DOC; (3) all costs for the design, development, fabrication, test, and verification of the ground segment would be shared equally by DOD and DOC; (4) all operations costs for the 5 year demonstration period would be shared equally by DOD and DOC; and (5) all costs associated with the experimental sensors which are not considered part of the triagency NOSS program, but which might be flown on the NOSS spacecraft, would be the responsibility of the sponsoring agency.

The MOU stipulated that NOSS data would be made available to the primary users (NOAA and Navy) and would "normally be unclassified." Data and command transmissions to and from the satellite, however, were to be "protected," and adequate protection for the satellites and the ground segment would be provided "to enable restricted access to selected data during times of emergency."

2. Support for NOSS

The NOSS program was not supported unanimously. Civilian scientists were satisfied with the comparatively low-cost Seasat type of satellite, while the Navy wanted a more sophisticated (and therefore more expensive) system with safeguards against hostile actions.[7] The costs for NOSS at the time the program was initiated were in the $600 million to $900 million range. One reason for the seemingly high cost was that it included all parts of the NOSS system, both in space and on the ground. While this total system cost approach to the program was applauded in some quarters for insuring that there would be no hidden costs to appear later, it was criticized elsewhere for providing fuel for NOSS critics by making the program appear exorbitantly expensive.

One scientist who vigorously opposed NOSS was Carl Wunsch, chairman of the Department of Earth and Planetary Sciences at the Massachusetts Institute of Technology, who argued that NOSS would fall short of what might be expected from such an expensive, long term program. In a November 1980 appearance before the National Advisory Committee on Oceans and Atmosphere (NACOA),

---

[7] Booda, Larry L. "NOSS: Plagued by Requirement Disagreements, Funding Delays." Sea Technology, September 1980. pp. 53–54.

Wunsch reportedly complained that the nongovernmental scientific community had not been consulted on the development of the system.[8] Despite Wunsch's concerns, NACOA strongly endorsed the NOSS program in a December 2, 1980, letter to the Office of Management and Budget (OMB).[9]

DOD was not entirely happy with the program either. Support for NOSS came from the Office of the Oceanographer of the Navy, and from the Office of the Secretary of Defense. The upper echelons of the Navy Department did not support the program, however, because of its high cost. This became a matter of considerable concern following the OMB directive that DOD would have to pay 50 percent of the cost for NOSS (see below).

NOSS did have strong support from the Carter administration, however, because it fulfilled goals enunciated in Carter's 1978 space policy directives, particularly in terms of interagency cooperation, the emphasis on space activities to meet needs on Earth, and as an example of increased military/civilian cooperation.

C. PROGRAM INITIATION

The three agencies had originally hoped to initiate the NOSS program in fiscal year 1980, with launch of the first satellite in fiscal year 1986. The program was presented to the OMB in 1978 during deliberations on the fiscal year 1980 budget, but OMB decided to defer the program, for essentially three reasons: a perceived lack of urgency to the program; the belief that NASA was paying too large a share of the costs; and a desire to look at other systems combining meteorological and ocean sensing to determine if a superior concept existed.

During consideration of the fiscal year 1981 budget in late 1979, the Director of OMB sent a letter to the three agencies stating that the R&D costs would have to be shared as follows: DOD—50 percent; NOAA—25 percent; and NASA—25 percent. In line with this breakout of costs, it was expected that for fiscal year 1981 DOD would request $12 million for NOSS, while NOAA and NASA would each request $6 million.

NOAA and NASA did include NOSS in their fiscal year 1981 budget submissions to Congress, but DOD did not because it had not yet decided whether it would agree to pay 50 percent of program costs. Eventually, the Secretary of Defense agreed to the cost sharing plan on the condition that the program would be reassessed prior to the fiscal year 1982 budget cycle, at which time the Navy would determine whether it could meet its objectives with a less expensive system (such as using sensors on other satellites). By the time DOD had reached this decision, however, the Reagan administration had come into office and cancelled the program (see below), so the funding was never actually requested from Congress.

Congressional consideration of the NOSS program was complicated by the fact that it was a triagency program, and therefore came under the jurisdiction of several different committees. Each agency had to justify the program to its congressional overseers independently of the others. Without a firm commitment from DOD to fund its half of the costs, consideration of the requests from NASA and NOSS were under strain. Funding was finally approved in the NASA funding bills, and funding for NOAA's share was also approved although a hold was put on the money until a commitment was made by DOD.

---

[8] Weather and Climate Report, November 1980. pp. 1-2.

[9] Ocean Science News, December 15, 1980. p. 5.

D. Program Termination

In 1981, the Reagan administration decided to terminate the NOSS program because it was not urgent, and was estimated to cost a considerable amount of money. Before leaving office, President Carter's budget recommendation to Congress had included $96 million for NOSS ($45 million for DOD, $35 million for NASA, and $16 million for NOAA). President Reagan's March budget request eliminated all funding for the program, and requested permission to rescind those amounts that had been included in fiscal year 1981.

Although budget constraints were a major factor in NOSS's termination, another problem was seen as an underestimation of the complexity of selling the program in Congress. As noted earlier, each agency had to justify the program to various congressional committees independently, with no single committee serving as a "sponsor" for the program. Thus, when President Reagan decided to cancel NOSS, there was no congressional constituency to fight for its restoration. The House Science and Technology Committee included language in its report on the NASA fiscal year 1982 authorization bill, however, stating that NASA should "investigate institutional arrangements for such a system which would replace the previous triagency arrangement." [10] The committee also stated that if DOD decided to pursue such a system for its own use, such a system should include a mechanism for providing data to the civilian community." [11]

E. Possible Replacement Program

Following NOSS's termination, the Navy began preliminary studies of an alternative, lower cost system which might be able to provide at least some of the data which had been expected from NOSS. Tentatively dubbed ROSS—for Remote Ocean Sensing System—the system would consist of only one satellite (rather than the two satellites plus a backup planned for NOSS), and would rely on existing technology. Although the program is only in the very beginning stages of definition, a cost figure of $130 million for ROSS has been estimated by the Navy.[12]

The Navy is discussing the ROSS concept with NASA and NOAA, and is considering how data might be made available to the civilian sector. One possibility would be to degrade the data, much as in the NAVSTAR program (see chapter 8). Preliminary discussions are also underway with the Canadians to see if a joint program might be possible (the Canadians might launch a compatible satellite of their own, for example).

---

[10] U.S. Congress. House. Committee on Science and Technology. Authorizing Appropriations to the National Aeronautics and Space Administration for fiscal year 1982; report to accompany H.R. 1257. 97th Congress, 1st session, May 8, 1981. H. Rept. 97-32. Washington, U.S. Government Printing Office, 1981. p. 22.

[11] Ibid.

[12] Based on telephone discussions with Cmdr. David Honharth, Office of the Oceanographer of the Navy, December 1981.

III. FUTURE PROPOSALS

No approved plans exist for launching dedicated ocean sensing satellites, although studies have been made for a variety of oceanographic satellite missions.

Phase A studies of the Ocean Topography Experiment [TOPEX] have been completed, and it may be included in NASA's fiscal year 1984 budget, with launch in late 1987 followed by a 5-year data collection period. TOPEX would measure the surface topography of the ocean over entire ocean basins using a satellite altimeter. TOPEX data would be integrated with conventional subsurface observations and models of the ocean's density field in order to determine the general circulation of the ocean and its variability. Information from TOPEX could contribute to an understanding of the nature of ocean dynamics, and could be used to calculate the heat transported by the ocean and the interaction of currents with waves and ice.

Conceptual studies have also been completed for Gravsat/Magsat, a satellite designed primarily for studying the Earth's gravity and magnetic fields. One objective of this proposed satellite is to provide information which could be used to produce a global map of the ocean geoid for use in ocean current and circulation studies. No launch date has been proposed for this mission and it has not been requested as a new program start by NASA.

The Free-Flying Imaging Radar Experiment [FIREX] is another future proposal, but is not as far along in development as the preceding missions. FIREX would involve placing a synthetic aperture radar on a free-flying spacecraft to make measurements of sea ice, oceans, and renewable and nonrenewable land resources. Preliminary discussions of FIREX have focussed on the potential of doing the program as a cooperative mission with Canada. Although no international agreements have been reached, and neither country has requested funds for FIREX, the suggestion has been made that Canada supply the spacecraft, primary sensor, and integration, while the United States would provide one or two secondary sensors and the launch vehicle.

CHAPTER SEVEN

GEODYNAMIC SATELLITES

I. INTRODUCTION

Geodesy is the science concerned with determining the size and shape of the Earth and the precise location of points on its surface. It is also often considered to include the determination of the Earth's gravitational field and the study of temporal variations such as Earth tides, polar motion, and the rotation of the Earth. Although estimates of the Earth's size have been made for centuries (Eratosthenes made the first recorded calculation of the Earth's circumference in the third century B.C.),[1] satellites enable more accurate calculations by acting as reference points in space for triangulation calculations. (The measured distances from a satellite in orbit to two separate ground stations can be seen as the two sides of a triangle whose baseline is the distance between those two points.) Also, the orbital perturbations of satellites can be measured to detect variations in the Earth's gravitational field, since relatively slight changes in gravity cause large dips and rises in a satellite's path.

The Earth's sphere is not perfect, nor is its rotation on the polar axis or the symmetry of its gravity field. Our planet has been shown to be slightly pear-shaped, in fact, and its equator is better described as an ellipse than a neat circle. There are bulges and hollows in the gravitational field that reflect differences in the concentration of the Earth's mass and which show up on maps as gravitational "highs" (hear New Guinea, for example) or as regions of low gravity (south of India).

The exact determination of the planet's shape and the absolute pinpointing of any two spots on its surface therefore, are involved mathematical and physical problems. As an approximation, geodecists construct an idealized gravitational model of the Earth known as the geoid to represent the outline of the mean sea-level surface, the basic reference shape on which the actual hills and valleys are superposed. Refining this geoid model is one of the main tasks of geodesy.

Precise geodetic measurements are more than an academic exercise and have many practical applications, including the targeting of military missiles and spacecraft bound for other parts of the solar system. For example, accurate measurements of the earth's gravitational field were required to send the Apollo astronauts off in the right direction toward the Moon from Earth orbit.

---

[1] For a review of historical geodesy, see: King-Hele, Desmond. "The Shape of the Earth." Science, June 26, 1976. pp. 1295–1300.

Geodetic measurements from satellites produce better maps of the Earth's surface and a more complete knowledge of its interior. The Earth's wobbles and density variations are clues to the nature of earthquakes, crustal plate motions, and perhaps to the location of mineral resources under its surface.

Satellite geodesy has produced excellent results already. As expressed by former NASA Associate Administrator for space Science, Dr. Homer Newell:

> The power of satellite geodesy was quickly evident, and significant results were forthcoming almost as soon as the satellites were available * * *.[2]

Results from satellite geodesy were capable of exploding old theories about the Earth and its internal structure:

> As John O'Keefe observes, the satellite results had forced the abandonment of what had previously been accepted as the basic hypothesis of geodesy. In brief, the hypothesis held that there are no extensive areas on Earth in which the difference between the Earth's gravity and the gravitational field to be expected from a uniform ellipsoid is of a single algebraic sign. The basic hypothesis stemmed from the concept of isostasy, in which the Earth was supposed to have an essentially plastic mantle in which stress differences would promptly be relieved. But satellite measurements revealed that there are substantial low-order harmonics in the Earth's field, casting serious doubt on the idea of a plastic mantle, and imposing serious limits on the idea of isostasy.[3]

Since the early 1960's, several techniques in satellite geodesy have been successfully applied: Optical camera sighting against star backgrounds; the sighting of flashing beacons aboard a satellite from several ground stations; radio Doppler tracking; radio ranging; laser ranging; and satellite-to-satellite tracking between low/orbiting satellites and high geostationary orbiters.

A number of new techniques are now being considered for future missions, including a pair of "drag-free' satellites in low orbit, gravity gradiometers, and radio interferometry from satellites.

The concept of garnering geodetic data from satellites was first articulated during preparations for the 1957-1958 International Geophysical Year (see volume 1, chapter 9). The earliest use of such data came in those same 2 years, when a worldwide network of scientists studied the positions of the Soviet Sputnik 2 and the American Vanguard 1 against the star background. The Vanguard observations eventually led to the discovery that the Earth is slightly pear-shaped.

Neither these satellites or the Transit navigational satellites (that later contributed to the design of the Anna geodetic spacecraft) were designed for geodetic experiments. Any satellite can be used for geodetic calculations, however, because all satellites travel in orbits determined by the Earth's gravity, and most have radio equipment for tracking purposes.

In 1958 and 1959 the United States attempted to launch two satellites specifically for geodetic purposes. Beacon Explorer 1 (October 23, 1958) and Beacon Explorer 2 (August 14, 1959) both failed to orbit, however. The first successful U.S. geodetic satellite program was Project Anna, a joint military/civilian effort. The desire of the military services to keep a security classification on geodetic data led to a split in these programs after Project Anna. Since military programs are outside the purview of this study, only the civilian satellites will be discussed. The NASA-sponsored geodetic satellites include some in the Explorer series discussed in volume 1, chapter 9, plus the GEOS, PAGEOS, and LAGEOS programs. See table 7-1 for a summary of NASA geodynamic satellite launches.

---

[2] Newell, Homer. "Beyond the Atmosphere: Early Years of Space Science." Washington, National Aeronautics and Space Administration, 1980. NASA SP-4211. p. 196.

[3] Ibid., p. 199.

TABLE 7-1
NASA Geodynamic Satellite Launches*

LAUNCH DATE**	SPACECRAFT	APOGEE (km)	PERIGEE (km)	INCLINATION (degrees)	COMMENTS
Oct. 23, 1958	Beacon Explorer 1				Failed to orbit.
Aug. 14, 1959	Beacon Explorer 2				Failed to orbit.
May 10, 1962	ANNA 1A*				Failed to orbit.
Oct. 31, 1962	ANNA 1B*	1,170	1,076	50.1	First spacecraft to carry a flashing light. Secor transponder failed, but data returned from beacon and Doppler experiments.
Mar. 19, 1964	Beacon Explorer A				Failed to orbit.
Oct. 10, 1964	Explorer 22 Beacon Explorer B	1,075	885	79.7	Primarily ionospheric research but carried corner reflectors for laser ranging.
Apr. 29, 1965	Explorer 27 Beacon Explorer C	1,315	940	41.2	Same as Explorer 22.
Nov. 6, 1965	Explorer 29 GEOS 1	2,277	1,115	59	
June 23, 1966	PAGEOS	4,286	4,198	87.1	Passive GEOS (mylar ballon).
Jan. 11, 1968	Explorer 36 GEOS 2	1,577	1,084	106	
Apr. 10, 1975	Explorer 53 GEOS 3	853	839	115	
May 4, 1976	LAGEOS	5,945	5,837	110	Laser geodynamic satellite.

* Joint with the Department of Defense in the case of ANNA 1A and 1B . ** Based on Greenwich Meridian Time. Compiled by Marcia S. Smith from data in: William R. Corliss. Scientific Satellites. NASA SP-133 (1967); NASA Historical Pocket Statistics; Appendix G of Volume I of this report.

II. PROJECT ANNA

The idea of using satellites for geodetic measurements preceded the creation of NASA, and became one of the first programs considered by the new agency in 1958. Through meetings of the Unmanned Spacecraft Panel of the Aeronautics and Astronautics Coordinating Board, NASA and DOD created plans for Project Anna, an acronym representing the various agencies expected to participate in the program—Army, Navy, NASA, and Air Force. (The Department of Commerce's Coast and Geodetic Survey also was involved.)[4]

Early in the program, a problem developed concerning whether the project and its resulting data should be classified. While scientists needed geodetic data for their own research into the nature of the Earth, the military required the data for missions such as the targeting of intercontinental ballistic missiles. According to NASA's Homer Newell, who chaired the Unmanned Spacecraft Panel at the time, the military wanted to make sure that potential enemies would be "forced to expend similar efforts to obtain the information" for missile targeting, rather than benefiting from the U.S. program through open dissemination of the data.[5]

The decision was made that Project Anna would be classified, and as a result, NASA withdrew from active participation (because of its commitment to an open program). In 1962, the program was declassified, and NASA resumed active participation.

While Project Anna itself played a relatively minor role in obtaining geodetic data (only one Anna satellite was successfully launched), it is important because it underscored the difficulties inherent in delineating between "military" and "civilian" space activities. Scientists were furious that Anna had been put under a security classification because they had conceived of geodetic satellites as a method of obtaining worldwide participation in a scientific study of the Earth. They were also concerned that DOD was not proceeding with the program as vigorously as NASA might if it were in charge of the program. After the debate over Project Anna, DOD and NASA continued to cooperate closely on geodetic satellite programs, but each built and operated their own satellites.

A. PROGRAM DESCRIPTION

Project Anna was designed as an array of several satellites (between four and six) launched into orbits with different inclinations and altitudes, although only two satellites (Anna 1A and 1B) were approved initially by Congress. Because Anna was based on technology used in the Navy's Transit navigation satellite (see chapter eight), the Navy was given management responsibility for the program through the Bureau of Naval Weapons.

Weighing 159 kilograms (heavy for that stage of the space program), the Anna satellites were the first to carry a flashing light (beacon). They also carried a radio ranging system and a Doppler ranging system. The three geomeasuring devices provided three different types of information: angle, range, and range rate (how fast the distance changed).

---

[4] Reorganization plan No. 4 of 1970 created the National Oceanic and Atmospheric Administration, of which the Coast and Geodetic Survey—renamed the National Ocean Survey—was made a part.

[5] Newell. Op. cit., p. 118.

The flashing beacon device involved optical camera observations by observers at several ground stations. The light would flash at precisely predetermined times, when it would be photographed against the star background. Using star charts, scientists could determine the satellite's apparent right ascension and declination. The resulting data were used to measure angle versus time, with an accuracy of 10 to 30 meters.

The radio ranging device, dubbed SECOR (for sequential collation of range) determined the distance between a ground station and the satellite by measuring the phase difference between a frequency-modulated radio signal sent to the satellite, then retransmitted back to the ground. This technique also provided an accuracy of 10 to 30 meters.

The third device, the Doppler ranging system, used a satellite transmitter with a frequency controlled by a very stable quartz crystal oscillator (the same oscillator used to control the clock which triggered the flashing light described above). The Doppler effect produced a shift in frequency which could be used to determine how fast the satellite moved with respect to the ground station, with an accuracy of 15 to 50 meters.

Scientists envisioned the geodetic satellite program as involving at least four different satellites in different orbits: one in polar orbit, one in equatorial orbit, one at 63.4 degrees inclination, and one in an orbit with a very high altitude. Launch vehicle technology available at the time made achieving such orbits difficult, so scientists settled for a compromise of 50 degrees in inclination for the first geodetic satellites, with the hope that additional objectives could be met as the program progressed and launch vehicles improved.

Ultimately, Project Anna was never authorized to proceed further than the two satellites which had been approved initially. The first of these, Anna 1A was launched on May 10, 1962, but did not achieve orbit because of a launch malfunction. Anna 1B was successfully launched on October 31, 1962, but the SECOR experiment did not function correctly. Good data were returned from the other two experiments, however. The satellite was placed in an orbit 1076 by 1170 kilometers, at a 50.1 degree inclination. Later geodetic satellites were launched by both NASA and DOD, but not as part of the Anna program.

B. 1962 House Science and Astronautics Committee Hearings

In May 1962, the matter of Project Anna's security classification became the subject of congressinal review.[6] Congressman Karth, chairman of the Subcommittee on Space Sciences of the House Committee on Science and Astronautics, wanted to know why Anna had begun as an unclassified program, was then classified, and then declassified again (an action taken by DOD just 17 days prior to the hearings). The subcommittee also addressed the issue of whether NASA or DOD should manage the program.

---

[6] U.S. Congress. House. Committee on Science and Astronautics. Subcommittee on Space Sciences. Project Anna—Geodetic Satellite System. Hearings, 87th Congress, 2d session May 14, 15, and 16, 1962. Washington, U.S. Government Printing Office 1962. 128 p.

The hearings began on May 14, 1962, four days after the first attempted Anna launch, which failed to reach orbit because of a launch vehicle malfunction. Witnesses at the hearings included: Lt. Cdr. Mark M. Macomber of the Bureau of Naval Weapons (who was in charge of the project); Dr. Harold Brown, Director of DOD Research and Engineering; Dr. Homer Newell, NASA's Director of the Office of Space Sciences; John D. Nicolaides, NASA's Director of Program Review and Resources Management in the Office Space Sciences; Rear Admiral H. Arnold Karo, Director of the Coast and Geodetic Survey; and Dr. Fred L. Whipple, Director of the Smithsonian Astrophysical Observatory.

1. Security classification of Project Anna

The interest of the subcommittee in the security classification issue as related to Project Anna stemmed from the comments of prominent scientists unhappy with this action. During the hearings, Congressman Karth congratulated Dr. Whipple for having brought the matter to the attention of the committee and stated that Whipple was in all probability the one man responsible for getting this program declassified.

According to testimony by the DOD and NASA witnesses, there had been no "decision" to classify Project Anna. Rather, as stated by Dr. Brown, programs in DOD are "born classified and have to be unclassified by some kind of action." NASA's Newell clarified the situation somewhat by saying that the idea of geodetic satellites had been unclassified in the beginning, but Project Anna specifically had not begun as an unclassifed program. He asserted that when DOD recommended in mid-1960 that the Anna data be classified, the NASA representatives of the Unmanned Spacecraft Panel did not feel that they were in a position to judge the question of whether or not the data should be classified. The Panel confirmed the DOD's desire to have the program classified because it felt DOD's needs were overriding. "So there was in effect an agreement that we would not press this matter further," even though the NASA representatives on the Panel did not feel there was complete justification for the security classification.[7]

Admiral Karo explained that his organization had opposed the security classification because "We felt that for worldwide information in geodesy, that it took all the scientists operating together. . . . We felt, also, that for normal purposes the data relationship around the world was sufficiently known, and so we could not see the necessity for classification."[8]

This latter point, that the data were already sufficiently known, was what ultimately led to DOD declassifying the project in April 1962. Dr. Brown told the subcommittee that he had found that there was already a considerable amount of unclassified geodetic information which had "quite good" accuracy. "The improvement that can undoubtedly be made by a still better program like the

---

[7] Ibid.
[8] Ibid.

Anna program is not considered by the Defense Department . . . to be important enough to alter the military situation particularly." [9]

Some scientists had charged that the classification of Anna had slowed the progress of the program, and subcommittee staff member Frank Hammill reported that Dr. James Van Allen had referred to the slow pace of the program as "almost a national dereliction." [10] Commander Macomber replied that Anna was one of the most complex satellites being built at the time and that there were problems with its construction, so the program was moving slowly. When asked if he felt the classification had affected the pace of the program, Macomber responded "No, sir. We went forward at the maximum rate on the satellite fabrication." [11] Admiral Karo, however, asserted that the scope of the program's scientific objectives had been narrowed by the classification issue because it limited the people "who could apply their thoughts and requests and information into the satellite." [12]

2. Management of the program

A complementary issue addressed at the hearings was why DOD, rather than NASA, had management responsibility for what was essentially a scientific satellite. NASA's Newell explained that Anna was based on technology from the Navy's Transit navigation satellite, so management was given to the Navy.

The subcommittee members thought that since the program had been declassified, management should revert to NASA. Dr. Brown reported that DOD did not feel possessive about the satellite, "but I don't think we can just make a transfer without thinking about the other problems . . . and the other agencies involved." Newell emphasized that the agreement between DOD and NASA on which agency should have responsibility for what programs focused primarily on cooperation on scientific programs, not that NASA should manage all of them. He stated that "DOD has management capability that we would like to see devoted to this program, just as we have asked them to undertake the management of our next ionosphere satellite attempts. . . . We would not want to shoehorn this out of the DOD and thereby perhaps interfere with the progress of the program." [13]

In its final report on the Project Anna issue,[14] the Science and Astronautics Committee noted that all witnesses had agreed to the scientific importance of establishing an effective U.S. geodetic satellite program, and that Project Anna should therefore be only the first step toward establishing such a program. With regard to the management issue, the committee concluded that:

> Although much of the information produced by a complete geodetic satellite system probably will have significant military implications, the data will have much broader scientific value and more general applications. Accordingly, the subcommittee believes that such a program logically falls within the responsibility of the Na-

---

[9] Ibid.
[10] Ibid.
[11] Ibid.
[12] Ibid.
[13] Ibid.
[14] U.S. Congress. House. Committee on Science and Astronautics. Project Anna-Geodetic Satellite System. Report, 87th Congress, 2d session. Aug. 8, 1962. Washington, U.S. Government Printing Office, 1962, p. 6–7.

tional Aeronautics and Space Administration rather than to the Department of Defense.

In its formal recommendations, the committee stated that NASA should again participate in the Anna program (there was only one more Anna launch), and that:

> In view of its responsibilities in the field of space sciences, and for international cooperation in the field of space exploration, NASA should prepare a detailed proposal for a follow-up geodetic satellite program designed to meet the needs of all interested parties, scientific and military. There is no apparent reason for postponing this step until after the first successful launch of the Anna satellite.
>
> NASA should assume management responsibilities for such a follow-on program, arrange for the necessary international cooperation, and provide for utilization of the talent and capabilities which exist in other agencies of the Government.[15]

3. *Aftermath*

Following the hearings, a policy board was established with membership from NASA, DOD, and the Department of Commerce (for the Coast and Geodetic Survey) to determine what direction the geodetic satellite program should take and give policy guidance.[16]

There was little effect on Project Anna per se because no further Anna satellites were approved. NASA announced during hearings on its fiscal year 1964 budget request that it was "getting underway for the preparation of the first firing of a Project Anna satellite" by NASA rather than DOD,[17] but this was done under the Explorer program (see next section).

NASA and DOD thus continued to cooperate in the area of geodesy, but each agency developed, launched, and operated its own satellites. As reported in 1980 by Homer Newell:

> It was finally agreed that the scientific geodetic program would continue, with open publication of results on the NASA side. Likewise, the DOD program would continue, and when appropriate the two agencies would cooperate, as with the Anna satellite. But DOD would decide unilaterally on the disposition of the data and results from its part of the program.[18]

In 1964, the National Geodetic Satellite Program (NGSP) was initiated as an interagency cooperation between NASA, the Departments of Defense and Commerce (Coast and Geodetic Survey), and various universities and international participants. Overall management of the program fell to NASA. Its objectives were to generate a unified geodetic reference network with an accuracy of 10 meters and to develop a more precise model of the Earth's gravitational field. The NGSP coordinated geodetic satellite activities throughout the 1960's in support of these goals.

---

[15] Ibid.

[16] See testimony of Homer Newell on NASA's fiscal year 1964 budget request. U.S. Congress. House. Committee on Science and Astronautics. Subcommittee on Space Science and Advanced Research and Technology. 1964 NASA Authorization. Hearings, 88th Congression, 1st session, Mar. 6, 7, 8, 11, 12, 13, 14, 19, 20, 21, 27, 28; Apr. 1, 2, 3, 4, 5, 8, 9, 10, 11, 24, 26, 29, 30; May 1, 8, 1963. Washington, U.S. Government Printing Office, 1963. pp. 1493-94.

[17] Ibid.

[18] Newell. Op. cit., p. 119.

III. EXPLORER SATELLITES WITH GEODYNAMIC MISSIONS

A. BEACON EXPLORERS A, B, AND C

In addition to the two Beacon Explorer satellites that failed to orbit in 1958 and 1959 (see Introduction), NASA launched five Explorer satellites equipped with geodetic devices.[19] The first three were designed primarily for ionospheric research. Beacon Explorer A, failed to reach orbit on March 19, 1964, due to a launch vehicle malfunction.

Explorer 22 (Beacon Explorer B) was launched successfully on October 10, 1964, and for the first time ground-based laser tracking was used for geodetic studies. The principle of laser ranging to a satellite is relatively simple. A ground station emits a narrow-beam laser light pulse, which bounces off optical reflectors fixed to the spacecraft back in the direction of the station. Since the speed of light is a known factor, a precise timing of the beam's round trip journey yields an accurate measurement of the distance to the satellite.

Explorer 27 (Beacon Explorer C), launched on April 29, 1965, was equipped with the same laser retroreflectors as well as ultrastable oscillators for Doppler tracking of orbital irregularities used to measure the Earth's gravitational field.

B. GEOS 1

The first successful all-geodetic satellite launched independently by NASA was Explorer 29, also known as the Geodetic Explorer or Geos (Geodetic Earth Orbiting Satellite 1). It was launched into a 2,217 by 1,115 km. orbit, high enough to avoid atmospheric drag, on November 6, 1965. The orbit was inclined at 59° to the equator.

Although each one of the five instruments on Geos 1 had been carried on some earlier spacecraft such as Anna, the Beacon Explorers or the Army's Secor, this was the most complete collection of geodetic instruments flown on one satellite up to that time; and, by cross-checking data from the different systems, the overall quality of geodetic measurements was improved.

The instruments were: Optical beacons that flashed four 670-watt bulbs at planned times for photography from Earth; a panel of quartz prisms that reflected laser beams for measurement of range and angle; a transponder for radio distance ranging; a radio becon for Doppler measurement of the satellite's rising and falling in its orbit due to gravity changes; and a supplemental range and range data antenna.

The desk-sized octagonal spacecraft was stabilized in orbit by means of a weight-balancing boom for gravity gradient stabilization to insure that the bottom baseplate containing the instruments always faced the Earth. The job of tracking Geos 1 fell to a number of ground facilities already established for other purposes. These included NASA's own Satellite Tracking and Data Acquisition Network [STADAN], the Deep Space Network used to track interplanetary spacecraft, and the Manned Space Flight Network made up of both fixed and transportable stations. (These networks are discussed in volume 1, chapter 4.)

---

[19] The Explorer program is discussed in detail in vol. 1, ch. 9.

In addition, the Army, Navy, Air Force, and Coast and Geodetic Survey contributed either tracking stations or cameras, as did the Smithsonian Astrophysical Observatory with its global network of high-precision Baker-Nunn cameras. The use of transportable stations allowed geodesists to extend the limits of their surveys to areas where there were no fixed facilities. The laser stations for tracking Geos 1 were similar to those first used in 1964 for Beacon Explorer B. They consisted of a ruby laser transmitter mounted with a receiving telescope. Like the Beacon Explorer, Geos 1 could only be tracked at night, and it was not until 1968 that orbital predictions became accurate enough for daytime laser ranging.

C. Geos 2

On January 11, 1968, NASA launched Geos 2, again as apart of the Explorer series (number 36). This mission was nearly identical to Geos 1 in purpose and instrumentation. The 1.2 meter diameter spacecraft was slightly heavier, with a weight of 207 kilograms as opposed to 173 kilograms for Geos 1.

Like its predecessor, Geos 2 carried experiments designed to improve the accuracy of satellite tracking as a means of refining gravitational and geometric models of the Earth. They included the same types of flashing beacons, laser cube-corner optical reflectors, Doppler radio transmitters and ranging radio transmitters that Geos 1 had carried. Geos 2 added an experimental radar transponder to test the applicability of C-band tracking to satellite geodesy.

Geos 2's orbit was more circular than that of Geos 1, with an apogee of 1,577 kilometers and a perigee of 1,084 kilometers, and was also more nearly polar, with an inclination of 106 degrees to the equator.

IV. PAGEOS

Between the launches of Geos 1 and Geos 2, NASA placed a different type of geodetic satellite into orbit around the Earth. The Pageos (Passive Geodetic Earth-Orbiting Satellite) spacecraft was launched on June 23, 1966, into a circular polar orbit with an apogee of 4,286 kilometers and a perigee of 4,198 kilometers. As its name suggests, Pageos was simply a passive target for optical sighting—a 30-meter mylar plastic balloon coated with aluminum to reflect sunlight. It carried no instruments.

The Echo 1 satellite, launched in 1960, was designed to reflect communications signals back to Earth and to study atmospheric densities, but those working on satellite geodesy in the early 1960's also found it ideal for optical tracking from ground-based cameras and used the Echo in triangulation calculations. In 1964 NASA approved the preparation of a similar reflective space balloon as part of the national geodetic satellite program.

Although Echo had been used frequently and was still being used for geodetic purposes in 1964, its orbital inclination made it impossible to track from polar latitudes, and its altitude was too low for simultaneous viewing across the span of oceans and continents. This prompted the decision to launch Pageos into a higher and more steeply inclined orbit, where widely separated ground stations could track it at the same time.

Like Echo, the Pageos sphere was inflated while in orbit, after being launched folded inside a small canister. The inside of the balloon was dusted before launch with anthraquinone and powdered benzoic acid, two inflating compounds. Benzoic acid turns to gas at a temperature of 46 degrees centigrade, so that, by holding the Pageos in a continuously sunlit orbit for a short time after launch, the powder was heated enough to expand into a gas that inflated the satellite.

Once inflated and in the proper orbit, Pageos was as bright as the star Polaris in the night sky, and it served as an excellent point source for geodetic triangulation calculations. Photographs were taken of the satellite against the star background from two or more separate stations just after dusk or before dawn, when the ground stations would be in darkness but the Sun would still be illuminating the sphere from below the horizon.

A coordinated global network of camera observation posts was key to the 5-year Pageos project, which was designed in support of the national geodetic satellite program's goal of establishing a single worldwide geodetic reference system. Using transportable and highly sensitive BC-4 Baker-Nunn cameras, 12 teams of observers from the Coast and Geodetic Survey and the U.S. Army Map Service traveled from one station to another throughout the world, staying at any one of some 40 different sites for periods ranging from 6 to 18 months at a time. As each party completed its operations at a given site, it would move on to another, after leaving behind a permanent survey mark.

By careful calculations of the distance and angle to Pageos from each station, and by correlation with simultaneous observations from adjacent stations, it was possible to create a linked geocentric network of baseline triangles that covered the surface of the Earth by project's end. Data from the Pageos observations were stored at the NASA Goddard Space Flight Center in Greenbelt, Md., for dissemination to the project's principal investigators, and so contributed to a measuring of the entire geodetic globe in a systematic way.

V. GEOS 3

Geos 3, although it bore the same acronym as Explorers 29 and 36, was not part of the Explorer series. In this case Geos stood for Geodynamics Experimental Ocean Satellite, because the satellite carried experiments pertinent to both geodesy and oceanography.

The Geos 3 satellite was launched April 10, 1975,[20] as part of NASA's new Earth and Ocean Physics Applications Program [EOPAP], which succeeded the earlier National Geodetic Satellite Program. The ocean-related mission objectives were to test a new satellite altimeter as a means of measuring the geometry of the ocean's surface and to use the same instrument for providing information on sea state, wave heights, and current systems. In addition, Geos 3, was designed to further refine methods of tracking a satellite in orbit by comparing Doppler, laser, radar, and satellite-to-satellite tracking methods.

---

[20] Based on Greenwich Meridian Time.

This improved orbital tracking accuracy was then to be applied to some current research problems in geophysics and geodesy: the detection of variations in the Earth's gravity and its polar motion and the tracking of continental drift and fault motions.

The Geos 3 spacecraft was similar in structure to Geos 2, but was considerably heavier (340 kilograms). It was launched into a nearly circular orbit inclined at 115 degrees to the equator and was stabilized by means of a gravity gradient boom.

Onboard were five experiments—an S-band transponder, a pair of C-band radar transponders, a Doppler beacon for radio ranging, an array of laser retro-reflectors, and a radar altimeter, the first ever carried on an unmanned spacecraft.

The S-band radar transponder was the key to a new satellite-to-satellite tracking experiment using NASA's ATS-6 satellite (see chapter 3) in high geosynchronous orbit. S-band ranging signals were sent from Geos up to ATS-6, which in turn relayed the signals down to the ground. By tracking Geos from above in this way, it was possible to measure short bursts of acceleration imparted to the satellite by Earth's gravity field, and to pinpoint more precisely its position in orbit. The ATS-6 satellite also contributed by relaying altimeter data down to the ground.

This two-satellite tracking experiment was supplemented by laser ranging, using the array of quartz reflectors encircling the satellite. With improved laser ground systems, tracking accuracy of 10 centimeters was possible. It was also supplemented by established Doppler tracking methods and by the use of C-band radar to provide another calibration reference for determining the spacecraft's position.

These various tracking methods were all cross-calibrated with the altimeter data in order to judge the value of the new instrument, as well as to further improve tracking accuracy. As a result, Geos 3 data were used to refine models of the geoid and measurements of the various wobbles, tides, and crustal movements in the solid Earth.

The Geos 3 radar altimeter was an especially important instrument, both to geodesists and to oceanographers. The basic concept of a spaceborn altimeter had been proved on the Skylab mission in 1973, with the Earth Resources Experiment Package [EREP]. The Geos altimeter beamed radar pulses down to the ocean surface, then timed their round trip back to the satellite after reflection off the water. This gave the altitude of the satellite with respect to the sea surface and made it possible to map the topography of the sea to within 1–2 meters. Since the satellite's height from the Earth's center of gravity was so precisely determined by the several tracking methods, it was also possible to apply these altimeter measurements to the problem of determining the shape of the marine geoid. It was particularly valuable in taking altimeter readings where no detailed surface gravity data had existed previously.

By 1980, Geos 3 altimeter data had been used in conjunction with Seasat measurements (see chapter 6) to produce a global 1 degree by 1 degree map of the mean sea surface with an accuracy of better than one meter.[21]

Another oceanographic application of the Geos 3 altimeter has been to measure the effects of deep ocean tides. Although there were early problems with factoring out perturbations in the satellite's orbit from altimeter data, the instrument has proved to be valuable in determining these tidal characteristics.[22] Geos 3 was also used experimentally to test the usefulness of altimeters in providing information on currents, wave heights, and wind speeds at the ocean surface, all of which can be determined from sea surface scattering of the altimeter's radar signal. Geos 3, and later the Seasat altimeter, demonstrated such a capability,[23] even though operation of the Seasat altimeter was shortened when that satellite failed in orbit a few months after its launch.

As of December 1981, the Navy was planning to launch its own satellite altimeter on the Geosat satellite in 1983. Based on the Seasat instrument, it was expected to yield altitude profiles to an accuracy of 10 centimeters.

An unexpected benefit from the Geos 3 altimeter was its ability to produce topographic contour maps of the land as well as the ocean. In an experiment conducted by the NASA Wallops Flight Center in 1978, Geos 3 altimeter profiles of the San Joaquin Valley in California were observed to agree with U.S. Geological Survey maps of the same area to within one meter. Since the altimeter was not designed to profile land surfaces, though, these measurements are restricted to gently rolling plains or valleys.

VI. LAGEOS

The Lageos, or Laser Geodynamic Satellite, was launched on May 4, 1976, as the first NASA satellite dedicated exclusively to laser ranging. Like the Pageos, this satellite is simply a passive reflective target, with no moving parts or electronics.

Lageos is an aluminum sphere approximately 60 centimeters in diameter, with a brass core that makes it heavy (406 kilograms) for its size. The solid sphere resembles a giant golf ball because of the array of 426 cube-corner-retroflectors made of fused silica spaced around its surface. These three-dimensional prisms reflect laser light back to its source regardless of the angle at which it is received.

The idea of orbiting a very dense and compact spherical laser reflector had been advanced since the earliest laser observations as a means of reducing the effects of solar photon pressure, gravity variations, and atmospheric drag on the precision of the orbit.[24]

At a seminar on solid-Earth and ocean physics held by NASA in 1969, geophysicists suggested that satellite techniques should be applied to the measurement of crustal motions, both on a continental scale and in closer detail near active faults. This was a strong motivation for attaining orbital accuracies of 10 centimeters or better.[25]

---

[21] NASA Geodynamics Program Office. Annual report for 1980. Washington, National Aeronautics and Space Administration. 1981. p. 24.

[22] Diamante, John M. and Nee, Tsun-Shi. "Application of Satellite Radar Altimeter Data to the Determination of Regional Tidal Constituents and the Mean Sea Surface." In Gower, J.F.R., editor. "Oceanography From Space." New York and London. Plenum Press. 1981. p. 907.

[23] Townsend, W. F., J. T., McGoogan, and E. J. Walsh. "Satellite Radar Altimeters—Present and Future Oceanographic Capabilities." In Gower, ed., p. 625.

[24] Project Lageos press kit. NASA press release No. 76-67. Apr. 15, 1976. p. 7.

The Earth's crust is thought to be broken up into a number of tectonic plates (today there are about ½ dozen large plates and a number of small ones) that move around on the planet's curved surface, possibly driven by convection cells in the hot mantle below. The continents lie on top of some of these plates, and modern plate tectonic theory holds that belts of folded mountains, and most earthquakes and volcanoes, are manifestations of the plates' splitting apart, colliding with, or sliding past each other. The accurate tracking of the direction and speed of plate motion therefore, has much to tell geophysicists about solid Earth dynamics that may possibly improve their ability to predict earthquakes.

The Lageos project was conducted as part of NASA's Earth and ocean physics applications program [EOPAP], which also included the 1978 Seasat ocean satellite (see chapter 6). The stated Lageos mission objectives were to provide an accurate reference point for laser ranging experiments dealing with plate motion, shifts in the polar axis, the maintenance of geodetic reference systems, and the accuracy of universal time.[26]

The laser ranging operations were similar to earlier satellite ranging. A narrow beam, pulsed every second from a ground station, was timed in its round trip from ground to space and back, giving the exact distance from that station to Lageos. By triangulating the Lageos-ground distances for more than one station, it was possible to determine the distance between those stations. Successive measurement of these distances should yield data on continental drift by telling scientists how the station locations changed distances with respect to each other over a period of time.

A key to the Lageos satellite's extremely accurate distance measurements is its exceptionally stable orbit. The orbit is very close to circular, with an apogee of 5945 km, and a perigee 5837 km. This orbit is also high enough to allow simultaneous viewing from stations located on different continents. The orbit is nearly polar, at an inclination of 110° to the equator, so that Lageos can also be viewed from high altitudes.

Because of the highly stable and precisely defined orbit, which allows the satellite's location to be known exactly at any given time, the total error in the distance measured from the ground to the spacecraft and back to the ground is less than 2 centimeters.

The stability of the orbit also means that Lageos will stay up for an estimated 8 million years, although the useful lifetime is expected to be only about 50 years. The knowledge that Lageos would survive far into the future before returning to Earth prompted Dr. Carl Sagan of Cornell University to prepare a "Message to the Future" similar to the Earth messages placed on board the *Voyager* and *Pioneer* spacecraft now headed for points unknown outside the solar system.[27]

Two identical copies of this message are etched on stainless steel sheets carried inside the Lageos sphere. They each contain a drawing of the Earth in orbit around the Sun, a guide to using the binary arithmetic used in the message, and three representations of the Earth as seen through geologic time. The first picture depicts the supercontinent of Pangaea, which geologists believe existed more than 225 million years ago, before the continents drifted apart to assume their present locations. The date of the "view" is marked in binary code. The second picture, similarly dated, shows world geography as it appears today. The third picture shows the world as geologists think it might appear 8.4 million years from now, when the drifting of crustal plates will have separated California and the horn of East Africa from their respective continents, widened the Red Sea and brought about other geographic changes.

---

[25] Ibid.

[26] Ibid., p. 6.

[27] These programs are detailed in volume 1, chapter 9.

The Lageos investigations were designed in two phases. The validation and applications phase, to last until 1982, is intended to perfect Lageos ranging to within 10 cm., although improvements in the laser trackers themselves have already provided some ranging in the 1-2 cm. range of error. For optimum plate-motion detection, there should be at least two tracking stations on every continent, with more stations monitoring fault zones. The goal of these Lageos plate motion experiments is to detect shifts in the plates to within one centimeter per year, averaged over four years. Successful plate motion measurement, then, requires continuous repeated observations, as do most geodetic experiments that relate individual positions on the globe to one another and to the Earth's center of mass.

There are both stationary and mobile laser [Moblas] ranging stations used in the Lageos observations as well as in other laser tracking projects. These ground laser stations have undergone a steady evolution since 1964 when the first fixed lasers were used for tracking the Beacon Explorer B. In addition to the fixed and Moblas laser stations, NASA has also developed a Transportable Laser Ranging Station [TLRS], and a TLRS 2 air-transportable laser is expected by 1982.

Mobility of lasers is an obvious advantage to taking frequent satellite geodetic measurements from many places around the world. The current Moblas system is movable, as its name implies, but the three months that it takes four vans to move equipment from one site to another has resulted in the use of Moblas lasers as nearly permanent base stations. The TLRS lasers are moved around typically to sites within a radius of 800 to 1,600 kilometers.

Movable lasers are operated for 1 to 2 months at a designated site, taking Lageos position measurements before being moved to another site. Sites are then re-visited after an elapsed period of time. Since these techniques are intended to measure accurately the drifting apart of separated stations, the lasers must be placed within one millimeter of their original location when repositioned at a site previously occupied.

The Smithsonian Astrophysical Observatory operates a network of four fixed laser stations, with sites in Arizona, Peru, Brazil, and Australia. In addition to the laser ground stations operating in Europe, Lageos is also tracked from fixed lasers located in Texas and Hawaii and at the Goddard Space Flight Center in Greenbelt, Md.

Tracking lasers have been positioned at many sites throughout the world since 1979, when the first mobile lasers were deployed outside the United States. In 1980, for example, lasers were located at Haystack Mass.; Ft. Davis, Tex.; Owens Valley, Calif.; Goldstone, Calif.; Kwajalein Island, American Samoa; and Yarragadee, Australia. Plans for 1982 include placing lasers in Mexico and Tahiti. There are currently eight Moblas stations in operation.

The Lageos laser-ranging is but one part of an interagency, multi-national geophysical program that involves not only the Lageos geodetic measurements but also laser ranging to other satellites and to cube-corner reflectors on the Moon left there by Apollo astronauts. Other similar geodetic techniques use fixed astronomical sources such as quasars as references for detecting plate motions.

An example of international cooperation in geophysics is the 1980–1981 Project Merit (Monitoring of Earth Rotation and Intercomparison of Techniques), which involved the United States, several European nations, Japan, Egypt, and Australia in a project to obtain data and design new methods of measuring variations in the rate and axis of rotation of the Earth. Merit was another program in which Lageos was used as a tool.

The San Andreas Fault Experiment [SAFE] was another such program. Initiated by NASA and the U.S. Geological Survey in 1972, the purpose of the SAFE was to monitor the motion of the North American and Pacific plates that grind against each other as they move in opposite directions along the San Andreas fault zone. The Lageos ranging data and other data indicated that the relative motion of the two plates is slightly faster than had been expected prior to the experiment.

In 1980, SAFE and several smaller projects were combined in NASA's Crustal Dynamics Project, conducted as part of a joint interagency effort authorized by Congress in the Earthquake Hazards Reduction Act of 1977 [28] with its goal to reduce the destruction caused by earthquakes through a better understanding of why and when they occur. The agencies involved are NASA, the U.S. Geological Survey, Defense Mapping Agency, National Oceanic and Atmospheric Administration, and National Science Foundation. The Project is responsible for developing both ground and space-based systems for monitoring movements of the Earth's crust.

In 1979, NASA selected 25 scientific investigators as part of a Lageos Working Group to conduct experiments using laser ranging data from the satellite. The experiments, representing both American and European investigators, were divided among studies of plate motion and deformation; variation in motion of the rotational axis; solid Earth and ocean tides; and satellite orbital perturbations. These investigations are to be completed by mid-1982.

In 1981 NASA selected another 56 experiments under the umbrella of the Crustal Dynamics Project, many of which will use Lageos data. The investigations are again concerned with crustal deformation and rotational dynamics, and include many regional studies of plate boundaries, among them a SAFE 2 experiment. Results from this batch of investigations are expected to be complete by the end of 1986. The Lageos satellite's contribution to these studies is to serve as the most stable reference point in Earth orbit for laser ranging.

---

[28] Public Law 95–124.

VII. PROPOSALS FOR FUTURE CIVILIAN GEODYNAMIC SATELLITES

In 1979, geodetic satellites were incorporated into the NASA Geodynamics Program conducted jointly with the Defense Mapping Agency, the U.S. Geological Survey, National Science Foundation and National Oceanic and Atmospheric Administration. This program is intended to coordinate and shape the future of satellite geodesy.

Geodetic satellites by 1981 had helped to define the Earth's gravity field, polar motion, and continental drift with high degrees of accuracy, and further research toward associating high and low gravity regions with structural and tectonic features continued. As part of the continued refinement of geodetic techniques, a new project has been designed that is expected to produce accuracies of 1 to 2 centimeters over baseline ground distances of 2-200 kilometers. Known as the SERIES (Satellite Emission Radio Interferometric Earth Surveying) Project, this technique will require no satellites of its own. Rather, SERIES would use radio signals from the Navstar—GPS (Global Positioning System) satellites already established by the Department of Defense for the purpose of pinpointing locations of ships and planes (see chapter 8). Six Navstar satellites are in orbit already, with 18 envisioned by 1987.

Military vessels and planes receive coded messages from the Navstar satellites, but the SERIES project, as well as non-military ships, will use specially developed receivers that pick up only the uncoded carrier phase of the signal for use in Very Long Baseline Interferometry [VLBI] studies. Geodesists already make use of distant quasars as radio sources for [VLBI] studies. Geodesists already make use of distant quasars as radio sources for VLBI interferometry, by comparing the signals at two widely separated ground stations. By analyzing the phase difference in these two radio signals, the distance between the stations can be determined.

A great advantage of the SERIES observations is that they will rely on radio sources that are much closer and therefore brighter than quasars. This allows for smaller, lighter, cheaper and more profitable ground observation stations and, thus, more flexibility in taking interferometric geodetic measurements around the world. The SERIES project is scheduled to get underway in 1983.

At the end of 1981 there were no geodetic satellites with funds already approved for the future. There are plans, however. A Geopotential Research Mission is planned for launch in the late 1980's that incorporates elements of both the 1979 Magsat satellite (see chapter 5) and the Gravsat Gravitational Satellite concept.

Requirements for a gravity field mission were first studied by the National Academy of Sciences in 1979, followed by a Gravsat User Working Group within NASA in 1980. A Federal Gravsat Panel was also established to foster joint agency participation.[29]

---

[29] NASA Geodynamics Program Office. Annual report for 1980. Washington. National Aeronautics and Space Administration. 1981. p. 12.

Now renamed the Geopotential Research Mission, the 7-month long investigation would involve two dense, drag-free satellites separated by 300 kilometers in a low (160 kilometer) orbit. The satellites would monitor each other's gravitational accelerations or decelerations by means of two-way coherent Doppler tracking and thus help to refine measurements of the Earth's gravitational field. A magnetometer on each satellite would also provide magnetic field readings.

This is known as the "low-low" concept of satellite tracking, as opposed to the "high-low" method used between Geos-3 and the geostationary ATS-6 in 1975. The Geopotential Research Mission satellites and expected to provide accuracies one order of magnitude better than do current methods of measuring gravity.

Even more sensitive as, well as more technologically challenging, would be the Gravity Gradiometer satellite envisioned for the 1990's, which would improve accuracies over the Geopotential Research Mission by another two to three orders of magnitude. Rather than orbiting two satellites, the gravity gradiometer concept calls for a single spacecraft containing two discrete masses cooled by cryogenic liquids. The relative accelerations and decelerations between these two balls would enable extremely precise calculation of gravity gradients.

In 1981, informal discussions were also underway between American and Italian scientific committees concerning the possibility of a second Lageos satellite. One scenario has the Lageos 2 launched by the space shuttle as a payload on an Italian test rocket stage. The satellite would be essentially the same as the first Lageos, but would be placed in an orbit phased at a different inclination to provide maximum night-time laser ranging capability from the ground to the two satellites.

CHAPTER EIGHT

NAVIGATION SATELLITES

Navigation was one of the first uses made of satellites—the first Transit satellite was launched in 1959. Although these programs are developed and funded by the Department of Defense, they have widespread civilian applications and are therefore included in this study. All U.S. navigation satellite launches are summarized in table 8-1.

The United States has proceeded through several developmental stages in navigation satellites. The Transit program has incorporated successive improvements since 1959, including the distinction of becoming the first satellites to use nuclear power sources (radioisotope thermal generators) in space. The Timation series and the Transit Improvement Program (which includes the new Nova satellites) further extended technology development. The next step in U.S. navigation satellites is the Navstar Global Positioning System, which will eventually utilize eighteen satellites in six co-planar orbits to provide continuous service for navigation needs. Six Navstar satellites have been launched successfully since 1978, but the system is not planned to be fully operational until 1988.[1]

In May 1981, the House Armed Services Committee voted to terminate the Navstar program because it is a "nice to have" rather than an "essential" system.[2] The Senate Armed Services Committee did not agree, however, and funding was provided for continued research and development (but not for procurement) in the fiscal year 1982 Department of Defense Authorization Bill. The future of the program remains uncertain, though, because the conferees stressed that continued congressional support for Navstar would depend on the priority given to the program by the Department of Defense.[3]

If Navstar proceeds, two issues which must be resolved are (1) whether to operate with eighteen satellites as currently planned, or with the twenty four satellites originally envisioned, and (2) under what conditions civilians will be able to use the system. Other navigation satellite issues include what agency should operate the systems, since they are used primarily by the civilian sector, but are funded by the Department of Defense; whether civilian users should be expected to pay some of development costs for new systems like Navstar; and what existing U.S. navigation systems should be phased out once Navstar is operational.

---

[1] For this report, initial operational capability [IOC] is defined as full operational status of the system for providing three-dimensional data, the goal of the Navstar program. Elsewhere, IOC has been used to designate when the system will be able to provide world-wide two-dimensional data, while three-dimensional availability is called FOC, for full operational capability. Using the latter definition, IOC is approximately 2 years prior to FOC.

[2] U.S. Congress. House. Committee on Armed Services. Department of Defense Authorization Act, 1982; report to accompany H.R. 3519. May 19, 1981. 97th Congress, 1st session. H. Rept. 97-71, Part I. Washington, U.S. Government Printing Office, 1981. p. 80.

[3] U.S. Congress. Committee of Conference. Department of Defense Authorization Act, 1982; report to accompany S. 815. November 3, 1981. 97th Congress, 1st session. H. Rept. 97-311. Washington, U.S. Government Printing Office, 1982. p. 90.

TABLE 8-1

U.S. NAVIGATION SATELLITE LAUNCHES

LAUNCH DATE*	SPACECRAFT	REMARKS
Sept. 17, 1959	Transit 1A	Failed to orbit.
Apr. 13, 1960	Transit 1B	Lower orbit than planned.
June 22, 1960	Transit 2A	
Nov. 30, 1960	Transit 3A	Failed to orbit.
Feb. 22, 1961	Transit 3B	Lower orbit than planned.
June 29, 1961	Transit 4A	
Nov. 15, 1961	Transit 4B	
Dec. 19, 1962	Transit 5A1	Command receiver failed.
Apr. 6, 1963	Transit 5A2	Failed to orbit.
June 16, 1963	Transit 5A3	Telemetry problems
Sept. 28, 1963	Transit 5BN1	Tumbled in orbit, recovered in inverted position (antenna pointing away from Earth).
Dec. 5, 1963	Transit 5BN2	
Apr. 21, 1964	Transit 5BN3	Failed to orbit.
June 4, 1964	Transit 5C	System became operational with this launch.
Oct. 6, 1964	Transit 0-1*	Satellite did not separate from secondary payload.
Dec. 13, 1964	Transit 0-2	
Mar. 11, 1965	Transit 0-3	Lower orbit than planned.
June 24, 1965	Transit 0-4	
Aug. 13, 1965	Transit 0-5	
Dec. 22, 1965	Transit 0-6	
Jan. 28, 1966	Transit 0-7	
Mar. 26, 1966	Transit 0-8	
May 19, 1966	Transit 0-9	

TABLE 8-1. U.S. NAVIGATION SATELLITE LAUNCHES (cont.)

LAUNCH DATE*	SPACECRAFT	REMARKS
Aug. 18, 1966	Transit 0-10	
Apr. 14, 1967	Transit 0-12	
May 18, 1967	Transit 0-13	
May 31, 1967	Timation 1	Quartz clock test.
Sept. 25, 1967	Transit 0-14	
Mar. 2, 1968	Transit 0-18	
Sept. 30, 1969	Timation 2	Quartz clock test.
Aug. 27, 1970	Transit 0-19	
Sept. 2, 1972	Triad (TIP 1)	First in Transit Improvement Program series.
Oct. 30, 1973	Transit 0-20	
July 14, 1974	NTS 1 (Timation 3)	Technology development flight; tested rubidium clock.
Oct. 12, 1975	TIP 2	Solar panels failed to deploy.
Sept. 1, 1976	TIP 3	Solar panels failed to deploy.
June 23, 1977	NTS 2	Technology development flight; tested cesium beam atomic clock. Part of NAVSTAR GPS program.
Oct. 28, 1977	Transat	Transit satellite equipped with redundant translators as part of Navy test of SATRACK receivers.
Feb. 22, 1978	Navstar 1**	First flight of new generation navigation satellite for Global Positioning System. All three atomic clocks failed prematurely.
May 13, 1978	Navstar 2	All three atomic clocks failed prematurely.
Oct. 7, 1978	Navstar 3	
Dec. 11, 1978	Navstar 4	
Feb. 9, 1980	Navstar 5	

TABLE 8-1. U.S. NAVIGATION SATELLITE LAUNCHES (cont.)

LAUNCH DATE*	SPACECRAFT	REMARKS
Apr. 26, 1980	Navstar 6	
May 15, 1981	Nova 1	First production version of TIP.
Dec. 18, 1981	Navstar 7	Failed to orbit.

---

* Launch dates are based on Greenwich Meridian Time, so may differ by a day from launch date based on local time at the launch site.

** Operational Transit satellites are sometimes referred to as OSCAR, and should not be confused with the amateur radio satellites of the same name. The first six Navstar satellites are sometimes referred to as NDS - for Navigation Development Satellite.

Table prepared by Marcia S. Smith from data contained in Appendix G of Volume I of this report, augmented by the annual Aeronautics and Space Report of the President and launch announcements in the media. Some of the information in the "Remarks" column is taken from: Geoff Richards. Transit — The First Navigational Satellite System. Spaceflight, Feb. 1979. pp. 50-55.

I. TRANSIT

The Transit program, also called the Navy Navigation Satellite System, began with the first Transit launch in September 1959 (which failed to orbit). After 13 more launch attempts, many of which suffered failures (see table 8-1), the Transit system was declared operational in 1964. Transit is an all weather, Doppler fixed source system, which provides two dimensional data to users, with accuracies on the order of 100 meters. (Better accuracies of as little as 10 meters can be achieved by stationary receivers, such as those on oil drilling platforms, by making repeated measurements.)

The chief disadvantage of Transit is that with only four to six satellites in orbit at a time, gaps exist during which readings cannot be made. Although the average time delay between usable passes of the satellites is on the order of 90-110 minutes (the closer the receiver is to the equator, the longer the time delay), there have been instances where the delay has been as much as 8 hours because of the failure of one satellite.

A. PROGRAM HISTORY

The idea of using satellites for navigation originated with the launch of Sputnik 1 on October 4, 1957. Scientists at Johns Hopkins University's Applied Physics Laboratory (APL) monitored that satellite and noticed that when the transmitted radio frequency was plotted on a graph, a characteristic curve of Doppler shift appeared.[4]

By studying this apparent change of radio frequency as the satellite passed overhead, they were able to show that the Doppler curve, when properly used, described the orbit of the satellite. Further study showed that by monitoring a single pass of the satellite, all of its orbital elements could be determined. Thus, navigation sets on Earth could use the known satellite position and Doppler observations of the satellite to compute positions.

The Navy's Polaris submarines required accurate position information for launching missiles, since missile accuracy is dependent upon the certainty of the position of the submarine at the time of launch. Thus, the Navy contracted with APL in 1958 to build navigation satellites based upon this new knowledge.

B. Program Description

The first Transit launch was attempted on September 17, 1959, but it failed to orbit when the third stage of the launch vehicle did not ignite.

On April 13, 1960, another launch was attempted and Transit 1B was placed in orbit, but not with the intended parameters. The satellite was a small sphere with a diameter of 0.9 meters. Most of the mass of the satellite (121 kilograms) was devoted to chemical batteries (a few solar cells were also carried). The satellite used two stable oscillators and two dual frequency transmitters (162/216 megahertz and 54/324 megahertz), and although the orbit was lower than planned, Transit 1B did demonstrate the operation of ultrastable oscillators in space.

Transit 2A, launched on June 22, 1960, was the first satellite to test fly an electronic clock, and also carried a Canadian cosmic radio noise experiment, thus giving it the distinction of being the first international satellite. Transit 3A, launched November 30, 1960, suffered a launch failure, and is most noted for the international incident it created when some of the debris from the launch vehicle fell on Cuba and purportedly killed a cow. Transit 3B also was affected by a launch vehicle malfunction which left it in a lower orbit than planned, but it was able to demonstrate the operation of a small magnetic memory system, and the Army's Sector transponder for geodetic measurements (see chapter 7 for a discussion of geodetic satellites), in its one month lifetime.

Transits 4A and 4B, launched on June 29 and November 15, 1961, respectively, tested improved memory cores and oscillators. They were cylindrical rather than spherical, and were the first satellites to use nuclear power sources (radioisotope thermal generators) in space.

The first prototype operational satellite, Transit 5A1, was launched on December 19, 1962, but the mission failed when the command receiver did not function properly. Transit 5A2 failed to orbit on April 6, 1963, while Transit 5A3, launched June 16, 1963, reached the proper orbit but experienced telemetry problems.

---

[4] Information on the history and functioning of the Transit satellites was based on: Geoff Richards. "Transit—the First Navigational Satellite System." Spaceflight, February 1979, pp. 50–55.

The next Transit series, 5B, represented the first satellites to rely entirely on nuclear power sources (radioisotope thermal generators, or RTG's). Transit 5BN1, launched September 28, 1963, tumbled in orbit and recovered in an inverted position, such that its antenna pointed away from Earth. On December 5, 1963, Transit 5BN2 was successfully launched and operated without failure.

Transit 5BN3 was lost in a launch failure on April 22, 1964, which caused another international incident when it was learned that a kilogram of plutonium (from the RTG) had been dispersed through the upper atmosphere over most of the southern hemisphere. As a result, Transit 5C reverted back to solar power. It was placed into orbit on June 4, 1964, and the Transit system was declared operational the next month.

Since June 1964, 17 Transit navigation satellites have been launched,[5] and the system has achieved a reliability record of 99.9 percent. Early problems with solar cell arrays which caused the spacecraft to cease functioning before their operational lifetime had been reached, were solved and subsequent Transit satellites have operated for as long as 10 years.

In July 1967, Transit was opened for use by the civilian sector, although some civilian oceanographic research ships had been equipped with transit receivers during the previous year. The number of civilian users (American and international) of Transit is now on the order of four to five thousand, and as of July 1981, represented 93 percent of Transit use.[6]

Civilian uses of Transit include oil exploration, ocean surveys, land surveys, aircraft position, commercial shipping, commercial fishing, and recreation. One difficulty for civilian users is that the system was designed for the military, and civilians must use the system at their own risk. Thus, if the Navy turns off one of the satellites without warning, there is no redress. This has led to the suggestion that operation of the system eventually be turned over to an agency such as the Coast Guard. This issue is explored further under the Navstar section.

C. TECHNOLOGY

The Transit system relies on stable satellite frequency transmissions to provide high levels of accuracy. To control transmitter frequencies, the satellites use ultrastable oscillators. Since the refraction of the satellite's transmissions by the ionosphere may cause inaccurate measurements, the transmitters operate on two frequencies so the user can measure the refraction and make requisite allowances in the calculations. The operational Transit satellites carry only one dual frequency transmitter, and are lighter than earlier models and can be launched by a Scout rocket.

The satellite is equipped with a memory core containing data on its orbital elements and the time of day, and broadcasts this information at 2-minute intervals. The memory can store 6,000 numbers, enough for 16 hours of operation. The information is updated in the satellite's memory core as it passes over "injection stations" located in Rosemount, Minn., and Laguna Peak, Calif., which also serve as tracking stations (together with stations at Prospect Harbor, Maine, and Wahiawa, Hawaii). The injection stations transmit commands updating orbital elements and time corrections to the satellite when it comes within range (approximately every 12 hours).

---

[5] The count of 17 includes the Transit launch on Oct. 28, 1977, but does not include launches of the Transit Improvement Program, Nova, Timation, or Navigation Technology Satellites. Operational Transit satellites are sometimes referred to as Oscar, and should not be confused with the amateur radio satellites (described in chapter 3) with the same name.

[6] Arlen J. Large. "Navigation Satellites Are Proving Useful to Many Users Besides the U.S. Military." Wall Street Journal, July 9, 1981.

The total radiated power of the satellite is 1.5 watts, meaning that antennas on the receivers can be relatively small. Current generation 5 megahertz oscillators have a stability one order of magnitude greater than those of the Transit 1B satellite, and have a drift rate of less than five parts in a hundred thousand million during a twenty minute pass. Current Transit satellites weigh approximately 60 kilograms and use solar panels for power.

To minimize atmospheric drag and provide a high Doppler shift, the satellites are placed in moderately high polar orbits at 1,000 kilometers, with a period of 107 minutes. A minimum of four Transit satellites are needed, but even with this many available, there are gaps during which data cannot be obtained. The average wait is 90–110 minutes (the length of time between usable passes increases closer to the equator), but there have been occasions when users have had to wait as long as 8 hours to take readings. One of the goals of advanced navigation satellite programs is to reduce or eliminate these time delays.

II. TECHNOLOGY IMPROVEMENT PROGRAMS FOR NAVIGATION SATELLITES

The Navy has continued to improve navigation satellites, and some of the developments include stronger transmitters, increased computer memory, improved reference clock stability, the capability to compensate for orbit disturbances, and attempts to harden the satellites against radiation. These improvements have been tested in the Timation/Navigation Technology Satellite series of launches, and the Transit Improvement Program [TIP]. The Nova satellites are the production version of TIP. Table 8–1 lists the launches that have been accomplished in these series. Timation/NTS is discussed below under the history of Navstar.

The first satellite in the TIP series was called Triad and was launched on September 2, 1972. It carried a new station-seeking and station-keeping system called DISCOS (Disturbance Compensation System), which compensated for the effects of atmospheric drag and solar radiation on the satellite's orbit. Triad also carried a new type of RTG for power. TIP 2, launched October 12, 1975, carried electronics which were hardened against radiation, a computer rather than a hard-wired memory core, and a system for correcting frequency errors in the clock by ground command. The mission reverted back to solar energy for power, and failed when the solar panels did not deploy. TIP 3 suffered the same fate after it was launched on September 1, 1976.

Despite the failures in the TIP series, the basic design for a new generation navigation satellite, Nova, was developed. The Nova satellite's are the production versions of TIP, and the first Nova launch was successfully accomplished on May 15, 1981. Two more are planned. The solar powered Nova satellites are placed in orbits like those of Transit, and weigh 368 pounds (166 kilograms) at launch. Nova provides faster and more accurate position fixes than Transit, requires fewer position update transmissions from ground stations, and uses a 25-foot (7.5 meter) long gravity boom for stabilization. Transit user sets are compatible with the Nova satellites.

III. NAVSTAR GLOBAL POSITIONING SYSTEM

The next step in U.S. navigation satellites is the Navstar (for Navigational System using Time and Ranging) system, also known as the Global Positioning System (GPS). [7] Ultimately, Navstar is designed to provide continuous, three dimensional (latitude, longitude, altitude) coverage of the entire globe by using eighteen satellites in six coplanar orbits. Six Navstar's had been launched successfully by the end of 1981, as part of the validation phase of the program.[8]

If the Navstar program continues, the full Navstar system is expected to be fully operational by 1988, although it is expected to provide a worldwide two-dimensional capability in 1986.

The primary goals of Navstar are to provide all-weather navigation for precision weapons delivery; enroute and differential navigation for land, sea, air, and space; photomapping, geodetic surveys, target reconnaissance, tactical control on land, sea and air; search and rescue; air and surface traffic control; barebase recovery, air drop, and close air support; and detection of nuclear explosions. Additional potential military uses include: missile guidance initialization/update; time transfer; instrument approach; bomb scoring; and range instrumentation. The civilian sector is also expected to use Navstar, but will receive degraded data (see below).

A. PROGRAM HISTORY

During the 1960's, the Navy and the Air Force were separately attempting to develop a highly accurate, three-dimensional navigation satellite system. These programs were combined in 1973 and renamed Navstar.

1. Navy program—Timation

The Navy program, begun in 1964, was called Timation, and was concerned with developing highly accurate three-dimensional navigational clocks. The program was based on the principle that given velocity and the time required for a radio signal to be transmitted between two points, the distance or range between the two points can be computed. For this concept, a precise, synchronized time of departure and measured time of arrival of the radio signal must be obtained. By synchronizing the signal transmission time to two precise clocks, one in a satellite and one at a ground-based receiver, the transit time could be measured and then multiplied by the exact speed of light to obtain the distance between the two.

---

[7] Operational Navstar satellites will carry an additional military sensor called IONDS (for integrated operational nuclear detection system), so the program is also sometimes referred to as GPS/IONDS.

[8] On Dec. 18, 1981, Navstar 7 was lost when its launch vehicle rose only 200 feet off the launch pad and then crashed.

The Navy Timation program envisioned a system of satellites in high-altitude circular orbits, testing the high precision clocks needed for this technique to work. The first two experimental passive ranging navigation satellites, Timation I and II, launched on May 31, 1967, and Sept. 30, 1969, respectively, carried quartz crystal standards and were able to demonstrate the feasibility of the passive ranging technique. However, experimental data revealed that crystal clocks could not be made sufficiently stable for long periods of time due to radiation aging of the crystals.

2. Air Force program—System 621B

In 1964, while the Navy was starting the Timation program, the Air Force's Space and Missile Systems Organization [SAMSO] began to look at the need for a highly accurate system to provide navigation information for aircraft. SAMSO concluded that satellites offered the best potential, and under a program called System 621B, conducted numerous studies between 1969 and 1972. The Air Force's preliminary plan called for three satellite constellations at 120 degree intervals over the equator, each with four satellites (one in geostationary orbit, the other three in slightly elliptic, inclined 24-hour orbits). This system would not have provided coverage for the polar regions, however. No recorded flight tests of this system were made, but ground tests apparently were made at an inverted range at Holloman Air Force Base in New Mexico (the inverted range concept is discussed further under the Navstar program description below).[9]

3. Combined program—Navigation Technology Satellites

In 1970, efforts began within the Department of Defense (DOD) to consolidate the development of navigation systems. In April 1973, the Navy Timation and Air Force 621B efforts were combined at the direction of the Deputy Secretary of Defense. The Air Force was designated the executive service for the joint program and directed to prepare plans for a comprehensive system based on the formerly separate programs. The consolidated effort included the orbit configuration of the Navy Timation plan (which would provide worldwide coverage without foreign ground stations), while the signal was based on the Air Force 621B concept.[10]

Timation III, which was renamed Navigation Technology Satellite 1 (NTS 1) after the programs were combined, was the first satellite in the Navstar development program. Launched on July 14, 1974, it tested two rubidium vapor atomic clocks (it carried two quartz standards as well), and operated at two different frequencies (335 Megahertz and 1580 Megahertz) to test dual frequency operation for improving accuracy. The satellite experienced tumbling in orbit, caused by solar wind pressure against the solar cell arrays.

---

[9] Geoff Richards. "Navstar—A Complete Global Navigation System." Spaceflight, Jan. 1, 1980. p. 3.

[10] Larry L. Booda. "Navstar: Three Dimensional Satellite Positioning with Ten Meter Accuracy." Sea Technology, March 1977. pp. 19–20.

This problem could not be corrected until 1975, but NTS 1 was able to achieve most of its goals.[11]

NTS 2, launched June 23, 1977, tested a cesium beam atomic clock, and had two L-band transmitters. This satellite was initially planned to serve as one of 4 satellites for use in testing Navstar, but a problem developed in a frequency synthesizer and the Navstar payload became inoperative.[12]

There had been plans to launch an NTS 3 to test a hydrogen maser clock, but this flight has been eliminated. The hydrogen maser clock will probably fly on a Navstar satellite sometime in the future.

B. PROGRAM DESCRIPTION

On December 22, 1973, the Deputy Secretary of Defense approved initiating the Navstar program based on the recommendation of the Defense System Acquisition Review Council [DSARC]. The program was designed in three phases: Phase I would provide for concept validation; phase II would be full-scale engineering development, test, and satellite production; and phase III would be production of user equipment and full operational deployment. A DSARC review of Navstar was completed in 1974 which allowed the program to proceed with phase I. A second DSARC review was held in 1979 which allowed phase II to start. A third DSARC will be held before phase III begins. As of December 1981, the initial operational capability (IOC) for the system was expected in 1988.

The Navstar program is managed by the Air Force through a Joint Program Office at the Air Force Space Division (formerly SAMSO), which includes representatives of the participating services (Air Force, Army, Marines, Navy, and Defense Mapping Agency), plus representatives of the North Atlantic Treaty Organization (NATO), and the Department of Transportation's Coast Guard (for civilian interests).

The total cost for the Navstar program through the year 2000 is now estimated at $8.6 billion. The original cost estimate for Navstar was $814.4 million (in 1973 dollars), but this did not include several items which have been subsequently added to the total program cost estimate (such as space shuttle launch costs, procurement of 19,261 user equipment sets for DOD, and 40 replenishment satellites required after IOC). A 1977 program restructuring also was responsible for increasing costs (see discussion below). Table 8-2 summarizes the escalation in Navstar program costs, and is based on information in a table prepared by the General Accounting Office in 1980.

---

[11] Philip J. Klass. "Frequency Standard Orbital Tests Set." Aviation Week and Space Technology, Oct. 11, 1976. p. 47.

[12] Everett D. Greinke. Statement of the Subcommittee on Transportation, Aviation, and Weather of the Committee on Science and Technology. U.S. House of Representatives. Sept. 27, 1978. p. 6.

TABLE 8-2

NAVSTAR COST ESTIMATES

DEVELOPMENT PHASE	PROGRAM COST ESTIMATES (in millions of then-year dollars) Dec. 1973	Feb. 1978	May 1979
Phase I	177.9	406.3	364.9
Phase II	253.4	679.6	839.7
Phase III	383.1	659.1	7,445.4
TOTAL	814.4*	1,745.0*	8,650.0**

* These estimates do not include any costs necessary to operate NAVSTAR beyond initial operational capability such as user equipment procurement costs, Space Shuttle launch costs, or replenishment satellites. Also, the program envisioned in the December 1973 estimate underwent substantial restructuring in 1977.

** This value extends the February 1978 estimate to include DOD's costs to acquire and maintain NAVSTAR through the year 2000, including such items as Space Shuttle launch costs, procurement of 19,261 user equipment sets, and 40 replenishment satellites.

Source: U.S. General Accounting Office. NAVSTAR Should Improve the Effectiveness of Military Missions -- Cost Has Increased. Report to the Congress by the Comptroller General. Washington, USGAO, February 15, 1980. PSAD-80-21. p.14.

The date of IOC has also slipped considerably. Originally envisioned for the 1984–5 timeframe, IOC slipped to 1986 as the result of the 1977 program restructuring, to 1987 because of internal DOD funding adjustments in 1979 and a 1980 program restructuring, and to 1988 during internal DOD funding adjustments in 1981.

1. Phase I

Phase I of the Navstar program, fom 1974 to 1979, involved a number of tests of the Navstar system at the inverted range of the Army's Yuma Proving Grounds in Arizona and the Navy's Fleet Operations Readiness Accuracy Test Site in California. The Yuma tests were made initially using ground-based truck mounted transmitters to simulate Navstar transmissions. Aircraft would then fly over the transmitters, rather than under them as would be the case if the transmitters were in space (hence the term "inverted range"). Laser trackers also were used to determine the position of the aircraft and these results were then compared with the position determined by the Navstar receivers.

As the Navstar satellites were launched, the tests transitioned to using satellites instead of the "inverted" equipment. (The Navstar satellites for the validation stages of the program are sometimes referred to as Navigation Development Satellites–NDS.) For the tests, enough satellites are needed such that four are visible over the North American continent at the same time for 4 hours per day.

In 1978, the first test was made using only satellites (no ground-based transmitters). At that time, three satellites were in orbit, and a test was made of a backpack receiver mounted in a truck moving 80 kilometers per hour. The test provided a horizontal accuracy of 6–7 meters.[13]

A total of 42 user sets were tested during phase I. Tests were made not only for military users of the equipment, but for the civil sector as well. For example, from May to September 1979, the Maritime Administration and the U.S. Coast Guard conducted joint tests of a Z-set receiver (see discussion below of "Technology—Receiver/User Sets") to determine the suitability of Navstar for marine use. The results were termed a "distinct success."[14]

2. Phase II

In June 1979, a second DSARC review was held, following which the Secretary of Defense gave the go-ahead for phase II of the program. In the spring of 1980, a significant restructuring of the Navstar proram was implemented because of budgetary constraints (see discussion below).

Former Under Secretary of Defense for Research and Engineering, Dr. William Perry, reported to Congress in 1980 on several tests he had participated in at the Yuma site, including the blind landing of a helicoper in a barren desert with Navstar as the only navigational aid; the helicopter landed within a few feet of its intended mark. He also participated in a rendezvous mission in which a helicopter flew directly to and hovered over a hidden armored personnel vehicle. In another test, a C-141 was used to drop supplies from the air using only the Navstar system for navigation, and the supplies landed within 30 and 40 feet (10 to 13 meters) of the intended drop point. Finally, he witnessed a blind bombing demonstration in which bombs without electronics or special guidance systems were dropped from airplanes. The accuracy of the bombs demonstrated substantial improvements over any previous results using other systems. (Although actual bombing accuracy is classified, a typical day's test results provided by DOD indicate less than 10 meter CEP.) [15],[16]

---

[13] Bruce A. Smith. First Navstar Test Results Exceed Goals. Aviation Week and Space Technology, November 27, 1978. p. 60.

[14] D. Feldman. Experiments in Marine Navigation with Navstar-GPS Satellites. Ocean Management, June 1981. pp. 71–83.

Other tests through 1981 have included guiding a Marine Corps landing craft to a predetermined point on a beach from more than a mile (1.6 kilometers) at sea. The craft landed within 25 meters of its intended destination.[17]

A final version of user equipment is being developed and tested during phase II, along with determining any necessary modifications to the satellites. Phase II is expected to be completed in March 1984.[18]

The most significant technical problem encountered with Navstar so far is failure of clocks. The first three Navstar satellites carried rubidium atomic clocks, each with backup crystal oscillators which could take over (with degraded performance) if the atomic clocks failed. All three of the atomic clocks on Navstar 1 and Navstar 2 failed. The problem was subsequently isolated as being caused by a chemical reaction between the rubidium and the wall of the vessel in which it was contained. The problem has been fixed, and subsequent rubidium clocks have performed well. Beginning with Navstar 4, a cesium clock has also been carried.

3. Phase III

Phase III will be the production and operational phase of the Navstar program and is currently planned to involve 18 operational Navstar satellites. Procurement of the operational Navstar satellites was expected to begin in fiscal year 1982, but Congress denied the funding (see discussion of congressional concern below). DSARC III, which will occur prior to initiation of phase III, is scheduled for May 1984.

4. 1977 program restructuring

By 1977, the Navstar program had begun encountering substantial delays, primarily because of technical problems related to developing the satellites and user equipment, and as a result, costs began to increase. DOD was unable to contain the costs within its fiscal year 1977 budget, so the agency restructured the program schedule as follows: launch of the first six satellites was extended from November 1977 to July 1978; completion of phase I was extended from March 1978 to February 1979; and IOC was extended from 1984 to 1985. Additional delays followed the program restructuring, however, and the last of the first six development satellites (Navstar 5) was not launched until 1980. Although phase I was completed in late spring of 1979, IOC slipped to 1986.

---

[15] CEP refers to circular error probable, a measurement unit for accuracy and refers to a 50-percent probability of attaining a certain accuracy.

[16] U.S. Congress. Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Science, Technology, and Space. NASA Authorization for fiscal year 1981. Part 3. Hearings, 96th Congress, 2d session. Feb. 21, 27, 29, and Apr. 3. 1980. Washington, U.S. Government Printing Office, 1980. pp. 1721-2. Additional information provided by the Office of the Secretary of Defense, March 1982.

[17] Aviation Week and Space Technology, Jan. 21, 1981. p. 13.

[18] John L. Hoerber. "An Update on Worldwide Navigation Systems—the Present and the Year 2000." Sea Technology, March 1981, p. 13.

Additional cost growth resulted from an increase in scope for the program. For phase I, scope changes included development of the NTS 3 satellite discussed earlier (which was subsequently eliminated) and a hydrogen maser clock, the award of contracts for developing alternative user sets, and procurement and launch of four additional satellites to support the Navy's Improved Accuracy Program. For phase II, changes were made to development plans for the satellites (to increase their life from 5.0 to 7.5 years, to make them compatible with the space shuttle, and to enhance their survivability) and to the user sets (including the addition of a second contractor to design the sets), and a decision was made to develop a dedicated command and control facility for Navstar.

The expected cost increase associated with the restructured program was estimated at $672.6 million, raising the program cost to $1.487 billion.[19]

5. 1980 restructuring of program

In the spring of 1980, following the DSARC review which recommended proceeding with phase II of the program, DOD again restructured the Navstar program, this time to reduce program costs in the 1981–1985 time period.

a. Reduction in number of satellites.—One effect of the restructuring was to reduce the planned number of operating satellites in orbit from the 24 which had been originally envisioned to 18. This is expected to reduce the accuracy of the system from 10 to 16 meters,[20] and increase the potential of users being unable to access four satellites usefully at one time (which is needed to obtain three-dimensional data).[21]

Neither of these impacts was judged to be critical to DOD. Instead, the military's greatest concern is the loss of resiliency in the system, such that if some satellites are lost (through hostile action or through satellite malfunction), the amount and quality of data that could be obtained from the system would fall more rapidly than if 24 satellites were available. One possible solution would be to store spare Navstar's in orbit to be activated when needed.[22]

Since this decision was based on funding constraints only, DOD hopes that eventually the system might be returned to the original 24 satellite configuration sometime in the future. One option being considered is multiyear procurement of the system, which might reduce production costs by as much as 10–15 percent.[23]

---

[19] U.S. General Accounting Office. "Status of the Navstar Global Positioning System." Report to the Congress by the Comptroller General. Washington, U.S. GAO, Apr. 25, 1978. PSAD–78–37. 24 pp. Some of the cost escalation was due to the inclusion of additional items (such as replacement spacecraft) in the later estimate. See table 8–2.

[20] Bruce A. Smith. "Navstar Program Changes Planned to Reduce Costs." Aviation Week and Space Technology, Apr. 14, 1980. p. 20.

[21] "Navstar Delay, Satellite Cut Planned." Aviation Week and Space Technology, Mar. 10, 1980. p. 16. The user actually "sees" four satellites, but the geometry is too poor to permit a three-dimensional position determination.

[22] "Navstar, With Only 18 Satellites, Loses in "Resiliency," AF Says." Aerospace Daily, Apr. 29, 1980. p. 327.

b. Delay in initial operational capability.—The restructuring of the program also delayed the expected date for initial operational capability (IOC) by one year to 1987 for the 18 satellite configuration. IOC may be further impacted by the congressional decision to delete procurement funding for Navstar from DOD's fiscal year 1982 (see discussion below).

c. Fortuna master control station cancellation.—Navstar program plans had called for construction of a Master Control Station at Fortuna Air Force Station, North Dakota. The site had been selected both for its potential survivability, and because its northerly location could take advantage of the highest number of satellite viewing hours per day. Construction of the control center was scheduled to begin in 1980. A facility at Vandenberg Air Force Base California was chosen for use during phase I and phase II of the program as an interim measure. As part of the restructuring, DOD decided to cancel plans to build the control center at Fortuna. Instead, a proposal has been made to incorporate the control center in the Air Force's Consolidated Space Operations Center [CSOC] planned for construction near Colorado Springs, Colo. If a final decision is made to place the control center at CSOC, it might be operational by 1985.

d. Block modifications to Navstar spacecraft.—A fourth result of the restructuring was to defer a major satellite block change for modifications to the Navstar satellites. There had been plans to increase power and hardening for the satellites and provide a new telemetry command system beginning with Navstar 13. Instead, it was decided to forego the changes in power and telemetry systems at least temporarily. The incresed power had been intended to permit greater versatility in operations using the manpack type of ground receiver and to provide greater resistance to jamming, but test results had reportedly shown that the existing Navstar design worked adequately in these areas.[24]

6. Congressional concern

Congress has maintained a close watch over the Navstar program, both through the authorization and appropriation process, and through studies by its investigative arm, the General Accounting Office [GAO]. Annual reports on the progress of Navstar have been issued by GAO since 1977.

Concerns about Navstar have centered on the program's schedule (which has slipped), its costs (which have escalated dramatically), and what access the civil sector will have to the system (and therefore whether they should help provide funding and whether DOD should operate the system or give it over to an agency such as the Department of Transportation.

The GAO now seems to support the Navstar program, although it has expressed concerns in the past about whether DOD had adequately studied the user market for the system within that agency, and the schedule and cost for the program. GAO, in fact, strongly recommends that Navstar replace several existing navigational aids, and is particularly interested in getting the Department of Transportation to commit itself to phasing out the Loran-C system in favor of Navstar.[25]

---

[23] "Navstar Nears Multi-Year Procurement Review." Aerospace Daily, Feb. 10, 1981. pp. 201–202.

[24] Smith, op. cit.

Congress provided the requested funding for Navstar through fiscal year 1982, but then, concerned about budgets in general and the slippage in the IOC for the Navstar program, eliminated procurement funding for the program and made a small reduction in research and development funding. In May 1981, the House Armed Services Committee reported out the DOD authorization bill, and denied all funding for the program.

> It is the judgment of the committee that the Navstar Global Positioning System is more of a "nice to have" than an "essential" military support system. If our defense needs were not so great, and the defense budget not so constrained, a case could have been made for the Navstar GPS. Because the system requires a total investment of over $8 billion, however, the committee does not believe that it is an affordable or prudent system to pursue.[26]

The Senate Armed Services Committee did not agree with this action when it reported out the same bill, and instead renewed its support of the program.[27]

On Novemeber 3, 1981, the conference report on the DOD authorization bill was issued. The conferees agreed to continue research and development for Navstar and provided $200 million ($166 million for the Air Force and $34 million for the Navy) for this purpose, but $21 million requested by the Army was denied. The $73.6 million requested for procurement of production satellites, and $34.4 million for Navy procurement of user equipment, was denied.

The conferees cautioned DOD that future congressional support should not be taken for granted, and suggested that DOD develop a plan for recovering some of the costs of the system from potential civilian users.

> The conferees believe the Department of Defense is unnecessarily shouldering the entire burden of the GPS development, acquisition and operating costs particularly recognizing that other Federal Government and civil uses for the GPS would be as numerous as military uses. The conferees therefore agreed that the Department of Defense should provide * * * a comprehensive plan for recouping from other Federal Government and civil users as much of the development, acquisition and operating costs of the GPS system as is deemed feasible* * *.
>
> The conferees are aware that the GPS has, at times, not enjoyed high priority within the services. The conferees wish to inform the Department of Defense that continuing congressional support for this program will be contingent upon the nature of the Department of Defense priority assigned in the development and fielding of this system and that any further slippage in the currently planned Initial Operational Capability [IOC] date may result in program termination.[28]

The language about further slippage in the IOC (which by this time had slipped by another year to 1988), was reinforced by language in the conference report on the DOD fiscal year 1982 appropriation bill which directed the agency to reprogram funds to maintain the current IOC.[29]

---

[25] U.S. General Accounting Office. "DOT Should Terminate Further Loran-C Development and Modernization and Exploit the Potential of the Navstar Global Positioning System." Washington, U.S. General Accounting Office, 1981. MASAD-81-41. Sept. 18, 1981.

[26] U.S. Congress. House. Committee on Armed Services, op. cit.

[27] U.S. Congress. Senate. Committee on Armed Services. Department of Defense Authorization for Appropriations for fiscal year 1982, report to accompany S. 815. May 6, 1981. 97th Congress, 1st session. Washington, U.S. Government Printing Office, 1981. p. 63.

[28] U.S. Congress. Committee of Conference, op. cit.

C. TECHNOLOGY

1. Satellites

The Navstar satellites are being built by Rockwell International. Because their primary purpose is for military uses, the satellites have many features to protect them against hostile attack (whether through an actual attack on the satellite with an antisatellite device, or through jamming). Navstar is expected to provide ten times more accurate radio navigation in general, and four times more accurate weapon delivery, providing position accuracy within 16 meters (with an 18-satellite configuration, which could be improved to 10 meters with 24 satellites); velocity accuracy within 0.1 meter per second; and time accuracy within 100 nanoseconds.

Navstar is a passive satellite system, such that the user does not need to query the satellite in order to obtain necessary positioning information. This type of system is advantageous because it can accommodate an unlimited number of users, and does not risk giving away the position of the user in a military situation. Data transmissions from the satellite provide the user with the time, the precise orbital position of the satellite, and positions of other satellites in the system. The user can calculate distance by measuring the time it takes for the satellite's radio transmissions, travelling at the speed of light, to reach the receiver. Once distance from four satellites is known, position in three dimensions (latitude, longitude, altitude) can be calculated by triangulation, and velocity in three dimensions can be computed from the Doppler shift in the received signals.

Like the Transit satellites, Navstar operates on two frequencies. To increase resistance to jamming, the signals are pseudo-random noise [PRN] modulated and use spread spectrum technology. The first signal, called C/A (for coarse acquisition), transmits at 1575.42 MHz and will be the only frequency available for civilian users of the system. The C/A signal is repeated every millisecond, enabling the ground receiver to align its internal clock with the satellite system's time reference. If four satellites are accessed, 30 meter accuracy can be obtained using just the C/A signal, although DOD has decided to permit an accuracy of only 200 meters for now (see section D). Military users will be able to access a second frequency sequence operating at 1227.6 MHz, which carries both the C/A signal and a P (for precise) signal with a repetition period of several days. Using the P code sequence, accuracies of 10 meters can be obtained with a 24 satellite constellation, and 16 meters with 18 satellites.

Navstar uses atomic clocks to provide the precise time information needed for this system. Each satellite now carries three rubidium clocks and one cesium clock. As noted earlier, problems with the rubidium clocks on early Navstar satellites have been solved, and hydrogen maser clocks are being developed. The satellites use solar panels for power supply, and are three-axis stabilized. The satellites weigh 760 kilograms at launch (455 kilograms in orbit), and are launched by an Atlas F vehicle (they will be launched by the space shuttle in the future).

---

[29] U.S. Congress. Committee of Conference. Making Appropriations for the Department of Defense for the fiscal year ending September 30, 1982, and for other purposes; report to accompany H.R. 4995. 97th Congress, 1st session. Dec. 15, 1981. Washington, U.S. Government Printing Office, 1981. p. 40.

A ground segment is needed to track and control the satellites in orbit, and to update data in the satellites memory banks. Orbital data and clock corrections are sent up to the satellites once a day via command and control data links which operate at 2227.5 MHz (downlink) and 1783.74 MHz (uplink). The ground segment headquarters is temporarily at Vandenberg Air Force Base, California, with three additional tracking stations in Hawaii, Alaska, and Guam. (As noted earlier, plans to build a Navstar Master Control Station at Fortuna Air Force Station in North Dakota were dropped, and the final control station is now planned for CSOC in Colorado.)

2. Receiver/user sets

The Navstar receivers are designed to solve automatically all necessary equations involving reception of signals from the four most favorably situated satellites, providing the user with position and velocity data. Six different classes of users for Navstar were identified by the Navstar Joint Program Office (JPO): (A) strategic bombers such as the B–52; (B) helicopters and fighter aircraft; (C) transport aircraft; (D) tanks and ships; (E) individual soldiers and ground vehicles; and (F) submarines. Later, an additional class M for missiles was identified.[30] To accommodate these several types of users at the least possible cost for each, four different receivers have been developed under JPO sponsorship.

The X-set is for users in categories A, B, and F, which require high accuracy, have high dynamics, and may be operating in severe jamming environments. One set, designed by Magnavox, has four channels capable of simultaneously tracking four different satellites, and provides continuous data in near real time. Texas Instruments has developed another set using five simultaneous channels, such that the set can switch over to a fifth satellite if one of the four it is accessing is about to go out of view, or if one channel is being jammed. Collins, a subsidiary of Rockwell International, has also developed a five channel X-set using narrow beamwidths to provide a high anti-jam capability. The X-set can operate with either one or two antennas, and can be complemented by other sensors such as inertial measurement units or air data units.

The Y-set is for users in class D, which have low dynamics and will probably operate in a low jamming environment. Built by Magnavox, it has only one channel which tunes sequentially to each of the four necessary satellites. Like the X-set, it can operate in conjunction with other sensors.

The Z-set is for users in class C, where low cost is a prime consideration. The Z-set operates only on the C/A frequency and is a single-channel sequential receiver like the Y-set. It cannot work with auxiliary sensors; Magnavox built the advanced development version of this set.

---

[30] Gowri S. Sundaram. "Navstar/GPS: A Unique U.S. High-Precision Worldwide Navigation System." International Defense Review, July 1979. p. 1145.

The manpack, for class E users, has special design constraints in terms of weight, power, and cost. Magnavox and Texas Instruments have both developed this type of user set, which uses single-channel sequential tracking like the Y- and Z-sets. It is designed to resist jamming and provides an interface for two-way data connection to an Army radio. The first manpack, weighing 14 kilograms (30 pounds) was delivered by Magnavox in September 1978.

The Class M user set, for missiles, smart bombs, and remotely piloted vehicles, is a special derivative and involves a low-cost reduced function unit that is initialized by Navstar data from another larger set in the launching vehicle.

Magnavox and Collins are currently competing (under parallel prototype development contracts) for the production of GPS user equipment. Each contractor is developing a complete family of sets for integration into multi-service land, sea, and air test platforms. These families of equipment are extensions of the X, Y, Z, and manpack advanced development set concepts, and package the equipment for integration into operational platforms by making them smaller, lighter, more rugged, etc. DOD intends to select one of these contractors to begin production in 1984.

Several other receiver sets have been developed outside of JPO sponsorship. Texas Instruments has developed a commercial receiver called the TI4100 for slow moving vehicles, with potential application for marine and geophysical exploration. TI4100 comprises an antenna, receiver, and control/display unit and weights 17 kilograms.

Magnavox has developed two users sets called GPSPAC and Sparton. GPSPAC is for use on spacecraft to establish real time position and velocity in low altitude orbits (such as Landsat and the space shuttle) and was sponsored by NASA and the Defense Mapping Agency. Sparton is an extremely low cost unit for military applications where less precise data can suffice, and can only access the C/A code.

D. CIVILIAN USE OF NAVSTAR

As noted previously, both Transit and Navstar are systems which have been developed by the military, primarily for military purposes. The civilian sector began using Transit in 1967, and at the present time, approximately 93 percent of Transit use is by civilians. Thus, it is expected that Navstar will also be made available to the civilian sector at some time in the future. The Department of Transportation [DOT] is the lead Federal agency responsible for civil navigation systems.

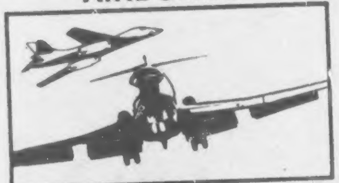
Typical civilian uses of Navstar are depicted in Figure 8-1; for comparison, figure 8-2 shows military uses of Navstar (both figures were provided by Rockwell International).

FIGURE 8-1

NAVSTAR
Global Positioning System

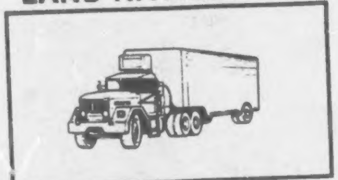
CIVIL APPLICATIONS

AIRBORNE



- APPROACH/LANDING
- OCEANIC ENROUTE
- DOMESTIC ENROUTE
- TERMINAL
- REMOTE AREAS
- HELICOPTER OPERATIONS

LAND NAVIGATION



- VEHICLE MONITORING
- SCHEDULE IMPROVEMENT
- MINIMAL ROUTING
- LAW ENFORCEMENT

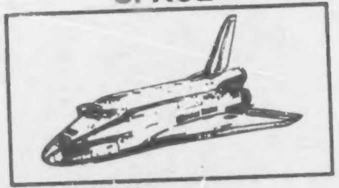
MARITIME NAVIGATION

- OCEANIC
- COASTAL
- HARBOR/APPROACH
- INLAND WATERWAYS

STATIC POSITIONING/TIMING

- OFFSHORE RESOURCE EXPLORATION
- HYDROGRAPHIC SURVEYING
- AIDS-TO-NAVIGATION
- TIME TRANSFER
- GEOPHYSICAL SURVEYING

SPACE



- LAUNCH
- IN FLIGHT/ORBIT
- REENTRY/LANDING

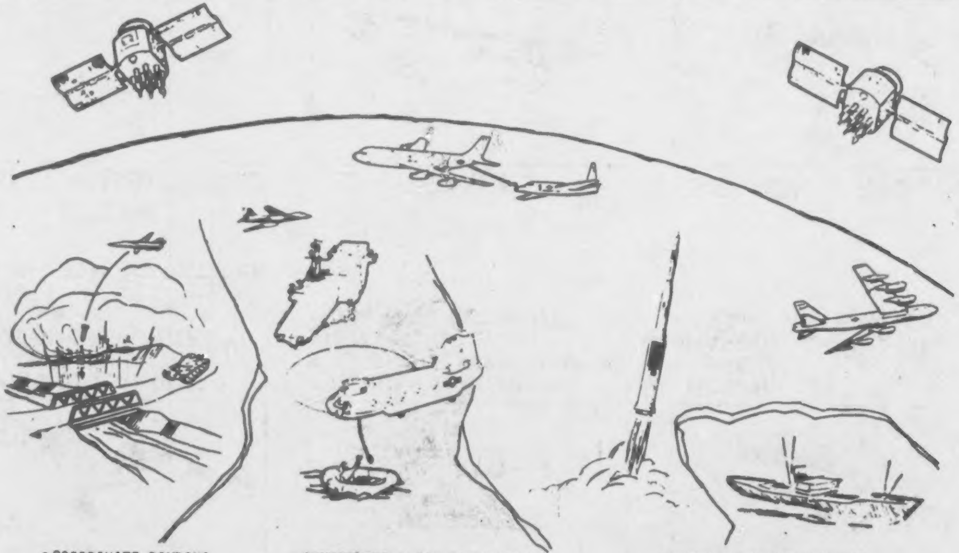
SEARCH & RESCUE

- POSITION REPORTING & MONITORING
- RENDEZVOUS
- REPEATABILITY OF POSITION
- COORDINATED SEARCH
- COLLISION AVOIDANCE

21SSD14928

FIGURE 8-2

TYPICAL MILITARY APPLICATIONS



- COORDINATE BOMBING
- BLIND BOMBING
- TARGET LOCATION

- RENDEZVOUS & AIR REFUELING
- SEARCH & RESCUE
- CARGO DELIVERY
- RELATIVE NAVIGATION

- MISSILE INITIALIZATION
- ENROUTE NAVIGATION
- TERMINAL NAVIGATION
- RANGE INSTRUMENTATION
- GEODESY & SURVEY

Rockwell International
Space Division

66CP7100

1. Conditions for civilian use of Navstar

As described under the section on Navstar technology, the civil sector will be allowed to access only the C/A band on Navstar, and therefore will not be able to obtain the very precise data that military users will have. The decision to provide only this "degraded" data to civilian users was made by DOD to deny access to the highly accurate positioning data to potential enemies, who could access the C/A data simply by obtaining a Navstar receiver such as those that will be available on the commercial market. DOD asserts that many civilian navigation needs can be met with the degraded data, although some applications will not, such as blind landings and harbor navigation. DOD has agreed to provide an accuracy of at least 200 meters from the C/A band with a 50 percent probability and to review the matter annually to determine if it would be possible to increase the accuracy available to the civil community.

DOD is also considering the possibility of encrypting the degraded data (as well as the highly precise data).[31] If the C/A data has the capability to be encrypted, DOD could deny access to all Navstar data in time of national crisis. If this route is chosen, it could have a significant impact on the decision over what navigation systems need to be retained as a backup to Navstar, since the civil sector would require alternative navigational aids if access to Navstar was cut off.

An alternative method of increasing accuracy for the civil sector is termed the "differential-Navstar mode" in which a special receiver would be installed in a terminal area (such as an airport). This special receiver would determine its position based on the C/A signal, determine the "local error," and continuously transmit a correction signal to aircraft via a data link. Tests of the differential mode have already shown that vertical accuracy is as good as 2 meters and horizontal accuracy 3.65 meters. The additional capability would result in increased cost of the receivers, however,

2. Potential of Navstar to replace existing navigation systems

Although there appears to be a consensus in the civil community that it wants access to Navstar, there is less agreement on what systems, if any, should be phased out once Navstar is operational. There are many different navigation systems now available for United States and international users. The scope of this study is only navigation satellite systems, and not those which rely on Earth-based transmitters. The latter are mentioned here only because of the potential of the Navstar system to replace some of them. Rockwell International, prime contractor for the Navstar satellites, prepared tables comparing the characteristics of many of the available navigation systems, which are reproduced in figures 8-3 through 8-6.

---

[31] "Pentagon Weighs Accuracy, Encryption of Civil Navstar Data."Aerospace Daily, June 12, 1980, p. 234.

FIGURE 8–3

NAV. SYSTEM COMPARISONS

NAVIGATION SYSTEM	METHOD USED: COORDINATES PROVIDED	2σ NAVIGATION ACCURACY	COVERAGE PROVIDED	USER SET COST	STATUS OF THE SYSTEM
NAVSTAR GPS	SPHERICAL RANGING: 3D POSITION 3D VELOCITY PRECISE TIME	POSITION = 80 TO 100 FT VELOCITY = 0.3 FT/SEC TIME = 10^{-7} SEC	GLOBAL (24 HRS PER DAY)	$5000 TO $45,000	6 SATELLITES IN 12-HR. ORBITS. AVAILABLE WORLDWIDE 1 TO 4 HRS/DAY 18-SATELLITE CONSTELLATION = 1987
TRANSIT	DOPPLER SHIFT: LONGITUDE LATITUDE	1500 FT	GLOBAL EXCEPT AT THE POLES (PERIODIC FIXES ONLY. TYPICALLY 1/2 TO 2 HOURS APART)	$10,000 TO $25,000	5 SATELLITES IN POLAR "BIRDCAGE" ORBITS >10,000 SETS IN USE 80% CIVILIAN USERS
LORAN C/D	HYPERBOLIC RANGING: LONGITUDE LATITUDE	GROUNDWAVE = 1500 FT SKYWAVE = 6000 TO 12000 FT	REGIONAL COVERAGE: ~10% OF EARTH	$2000 TO $10,000	8 LORAN C CHAINS WITH 34 TRANSMITTERS COVER ABOUT 10% OF THE EARTH
OMEGA	HYPERBOLIC RANGING: LONGITUDE LATITUDE	12,000 TO 24,000 FT	ESSENTIALLY GLOBAL 88% COVERAGE BY DAY 98% BY NIGHT	$3000 TO $80,000	8 TRANSMITTING STATIONS IN OPERATION WORLDWIDE
VOR/DME TACAN	LIGHTHOUSE SIGNAL + SPHERICAL RANGING: HEADING SLANT RANGE	200 TO 600 FT (3° ANGULAR ERROR)	LINE OF SIGHT ALONG PRESENT AIR ROUTES	$500 TO $2000	MORE THAN 1000 TRANSMITTERS IN OPERATION. AT LEAST 250,000 USERS

Space Operations and Satellite Systems Division

Rockwell International

61SSD18784 A

FIGURE 8–4

NAV. SYSTEM COMPARISONS

NAVIGATION SYSTEM	METHOD USED: COORDINATES PROVIDED	2σ NAVIGATION ACCURACY	COVERAGE PROVIDED	USER SET COST	STATUS OF THE SYSTEM
NAVSTAR GPS	SPHERICAL RANGING: 3D POSITION 3D VELOCITY PRECISE TIME	POSITION = 80 TO 100 FT VELOCITY = 0.3 FT/SEC TIME = 10^{-7} SEC	GLOBAL (24 HRS PER DAY)	$5,000 TO $45,000	6 SATELLITES IN 12-HR. ORBITS. AVAILABLE WORLDWIDE 1 TO 4 HRS/DAY 18-SATELLITE CONSTELLATION = 1987
ILS/MLS	BEAM STEERING: HEADING ELEVATION RANGE	15 TO 30 FT (0.05° ANGULAR ERROR)	LINE OF SIGHT: 17 TO 35 N.MI. AVAILABLE ONLY AT PROPERLY EQUIPPED AIRPORTS	$1000 TO $2000	HUNDREDS OF SYSTEMS OPERATING WORLD-WIDE. 120,000 + DOMESTIC USERS
INERTIAL NAVIGATION	INTEGRATING ACCELEROMETERS: 3D POSITION 3D VELOCITY	500 TO 5000 FT (ACCURACY DEGRADES BETWEEN UPDATES 200 TO 60,000 FT/HR)	GLOBAL WITH PERIODIC UPDATES	$50,000 TO $1,000,000	THOUSANDS OF SELF-CONTAINED UNITS IN USE ON CIVILIAN AND MILITARY PLANES AND SHIPS
JTIDS RELNAV	ACTIVE AND PASSIVE SPHERICAL RANGING: 2D POSITION 2D VLOCITY (ALTITUDE IF GEOMETRY IS FAVORABLE)	200 TO 300 FT (USUALLY RELATIVE)	LINE OF SIGHT: AVAILABLE ONLY IN LOCAL BATTLEFIELD AREAS	MODERATE: SOFTWARE ONLY. BASIC JTIDS TERMINALS COST $150,000 TO $200,000	DEVELOPMENTAL SYSTEM FOR USE BY A/F VEHICLES IN CONJUNCTION WITH JTIDS COM NETS
PLRS	ACTIVE AND PASSIVE SPHERICAL RANGING 2D POSITION	200 TO 300 FT (USUALLY RELATIVE)	LINE OF SIGHT: AVAILABLE ONLY IN LOCAL BATTLEFIELD AREAS	MODERATE: SOFTWARE ONLY (TOTAL MANPACK COSTS ~$15,000 INCLUDING COM)	DEVELOPMENTAL SYSTEM FOR USE BY ARMY USERS IN CONJUNCTION WITH PLRS COM NETS

Space Operations and
Satellite Systems Division

Rockwell
International

61SSD18785A

FIGURE 8-5

MILITARY NAVIGATION SYSTEM COMPARISON

SYSTEM	COVERAGE	ACCURACY	COMMON GRID	PASSIVE USER	USER NO. LIMITATION	JAMMING IMMUNITY	AMBIGUITY	SELECTIVE DENIAL
INERTIAL	WORLDWIDE	TIME VARIABLE	SINGULAR	YES	NONE	INFINITE	NONE	NA
DOPPLER	WORLDWIDE	TIME VARIABLE	SINGULAR	NO	NONE	NONE	NONE	NA
LORAN C	LIMITED ~ 14%	MODERATE – 150 m	NONE	YES	NONE	NONE	SLIGHT	NO
LORAN D	THEATER ONLY	MODERATE	NONE	YES	NONE	MINIMAL	SLIGHT	NO
DECCA	LIMITED	MODERATE	NONE	YES	NONE	NONE	SLIGHT	NO
OMEGA	WORLDWIDE	2000 m	NONE	YES	NONE	NONE	SEVERE	NO
TRANSIT	WORLDWIDE	50 m	WGS-72	YES	NONE	NONE	VELOCITY AID	NO
RADIO BEACON	REGIONAL	LOW	SINGULAR	YES	NONE	NONE	SLIGHT	NO
VOR/DME	REGIONAL	LOW	SINGULAR	NO	LIMITED	NONE	NONE	NO
TACAN	REGIONAL	MODERATE	SINGULAR	NO	LIMITED	NONE	NONE	NO
MLS/ILS	TERMINAL AREA	RANGE DEPENDENT	SINGULAR	YES	NONE	NONE	NONE	NO
PLRS	SECTOR NET	30 m	SINGULAR	NO	LIMITED	25+ dB	SLIGHT	CODE KEY
JTIDS RELNAV	SECTOR NET	30 m	SINGULAR	NO	LIMITED	30+ dB	SLIGHT	CODE KEY
NAVSTAR GPS	WORLDWIDE	16 m	WGS-72	YES	NONE	55 dB	NONE	YES

IMPORTANT FOR COMBINED FORCES OPERATIONS

Space Operations and Satellite Systems Division

Rockwell International

41SSD16881

FIGURE 8–6

MILITARY
NAVIGATION SYSTEM COMPARISON (CONT.)

SYSTEM.	CONTINUOUS NAVIGATION	3 DIMENSION	VELOCITY DATA	HIGH DYNAMIC OPERATION	ALL WEATHER	PROPAGATION LIMITATION	AUTONOMOUS U.S. GROUND CONTROL	TIME DISSEMINATION	COST
INERTIAL	YES	WITH BARO	YES	YES	YES	NONE	NA	NONE	EXPENSIVE
DOPPLER	YES	YES	YES	YES	RAIN/ALTITUDE	ALTITUDE	NA	NONE	MEDIUM
LORAN C	YES	NO	CRUDE	DEGRADATION	MODERATE	WARP	YES	MODERATE	MODERATE
LORAN D	YES	NO	CRUDE	DEGRADATION	MODERATE	WARP	YES	NONE	MODERATE
DECCA	YES	NO	NO	DEGRADATION	MODERATE	WARP	NO	NONE	MODERATE
OMEGA	YES	NO	NO	DEGRADATION	MODERATE	IONOSPHERE	NO	SLIGHT	LOW
TRANSIT	CYCLIC	NO	NO	NO	MODERATE	IONO 2 FREQ	YES	MODERATE	MEDIUM
RADIO BEACON	RELATIVE	NO	NO	DEGRADATION	SLIGHT	TERRAIN	NO	NONE	LOW
VOR/DME	RELATIVE	NO	CRUDE	DEGRADATION	SLIGHT	TERRAIN	NO	NONE	LOW
TACAN	RELATIVE	NO	CRUDE	DEGRADATION	SLIGHT	TERRAIN	YES	NONE	LOW
MLS/ILS	RELATIVE	YES	CRUDE	YES	YES	TERRAIN	NO	NONE	MODERATE
PLRS	RELATIVE	NO	NO	SLIGHT	YES	L.O.S.	YES	RELATIVE	MEDIUM
JTIDS RELNAV	RELATIVE	LIMITED	CRUDE	SLIGHT	YES	L.O.S.	YES	RELATIVE	EXPENSIVE
NAVSTAR GPS	YES	YES	YES	YES	YES	NONE	YES	YES	MEDIUM

SIGNIFICANT FACTORS FOR
WEAPON DELIVERY

Space Operations and
Satellite Systems Division

Rockwell
International

41SSD16882

a. 1978 and 1981 General Accounting Office Studies

In March 1978, the General Accounting Office (GAO) issued a report on the "proliferation" of navigation systems and commented that Navstar, whcih can provide allweather, global, three-dimensional position information, should be able to replace many of the existing civil and military systems. Thirteen navigation systems were reviewed by GAO, of which only 4 were deemed necessary by the agency in the long term. Those systems which GAO recommended for retention were: Navstar as the primary navigation system for most land, sea, and air users; self-contained inertial and Doppler radar systems for jam-prooof and sabotage-free military operations, and as a backup for some civil aviation; and the Coast Guard's marine non-directional beacons as a low-cost, low-accuracy system for small watercraft. The agency also concluded that Omega and civil aviation nondirectional beacons would be needed for at least several years.

Systems which GAO concluded could be phased out as Navstar began operation, and therefore should not be developed, modernized or expanded, were: VOR, TACAN, LORAN-C, LORAN-D, Transit, the navigation portion of PLRS, and the military's nondirectional beacons. (Loran-A had already been scheduled for phase out, and the Navy had terminated its differential Omega development at the time the study was prepared.)[32]

In a 1981 report, the GAO reaffirmed its recommendation on Loran-C, stating that the Department of Transportation (DOT) should terminate plans to modernize that system, and stated that the Coast Guard had "devoted little effort to velauating and developing" Navstar's civil uses.[33]

b. 1980 Federal Radionavigation Plan Recommendations

In 1980, the U.S. Government issued a Federal Radionavigation Plan, which is described in more detail below. Regarding the issue of what systems might be phased out once Navstar is operational, the plan stated only that a process had been developed between DOD and DOT for determining what navigation systems will be needed in the future. According to the report, the process "represents a conordinated DOD/DOT effort to resolve all outstanding issues and to recommend the optimal choice for the overall national interest by 1986."

The 1986 date represents two different time lines. According to the plan, DOT and DOD would complete technical evaluations of the candidate systems, including Navstar, in 1982. Also at that time, a joint DOD/DOT economic planning model would be completed and enable an analysis of the costs and benefits of the different possible mixes of existing systems and those under development. These actions would be followed by 3 years of consultations with domestic and international groups which would be affected the decision.

---

[32] U.S. General Accounting Office. "Navigation Planning—Need for a New Direction"; report to the Congress by the Comptroller General of the United States. Mar. 21, 1978. Washington, U.S. General Accounting Office, 1978. LCD-77-109.

[33] U.S. General Accounting Office. "DOT Should Terminate Further Loran-C Development and Modernization and Exploit the Potential of the Navstar/Global Positioning System." Sept. 18, 1981. Washington, U.S. Government Printing Office, 1981. MASAD-81-42.

c. 1981 DOD recommended schedule of system phaseout

In October 1981, DOD provided its own schedule for phasing out its use of those navigation systems which it felt could be replaced by Navstar to the House Armed Services Committee, including the phaseout period, and expected cost savings. This information is shown in table 8-3. Note that the schedule is strictly for DOD phase out of the systems, and does not necessarily reflect a recommendation on when the civil sector should stop using them.

TABLE 8-3

SYSTEMS TO BE REPLACED BY NAVSTAR GPS IN DOD

SYSTEM	PHASE OUT*		ANNUAL COST AVOIDANCE**
	START	END	
Automatic Direction Finding (ADF)	1987	1996	$ 4.85
Non-Directional Beacon (NDB)	1995	1996	2.37
Direction Finding (DF)	1995	1996	1.03
Very High Frequency Omni Directional Radio Range (VOR)	1987	1996	4.56+
TACAN	1987	1996	68.02
DME	1987	1997	.45
RAYDIST/ARGO/Mini-Ranger	1987	1996	3.53
Loran	1987	1992	12.44
Transit	1987	1992	22.83
Omega	1987	1996	14.00++
Electronic Altimeter	1987	1996	19.35+
			$153.43

* Begins at NAVSTAR Initial Operational Capability and lasts 10 years unless shown otherwise in the Joint Chiefs of Staff Master Navigation Plan.

** FY81 dollars in millions, estimate based on FY80-FY82 experience. Cost includes RDT&E, acquisition, modification, reprocurement and O&M.

+ Forty percent of VOR/ILS and electronic altimeter costs are assumed saved when NAVSTAR replaces VOR and high altitude electronic altimeters.

++ Includes all Army, Air Force, and 75 percent of Navy costs (certain Navy platforms plan continued use of Omega as a back-up system to NAVSTAR).

Source: Office of the Secretary of Defense/Communications, Command, Control and Intelligence. October 1981.

3. The 1980 Federal Radionavigation Plan

In 1980, the U.S. Government completed a four-volume Federal Radionavigation Plan [FRP] as part of the effort to develop a coordinated military/civilian framework for navigation systems.[34] Prior to the 1980 plan, military navigation policy was contained in the 1978 edition of the Joint Chiefs of Staff—Master Navigation Plan, while civilian policy was contained in the DOT National Plan for Navigation, which had been originally published in 1970, and later reissued with some policy changes in 1972 and 1977. The FRP delineated the various responsibilities for navigation system development in the Federal Government, and identified issues which need to be resolved prior to a final Government decision on what systems to retain and develop for the future.

a. Responsibilities of various Federal agencies for navigation systems.—In the U.S. Government, responsibility for navigation systems is split between DOD and DOT. DOD is responsible for developing, testing, evaluating, operating, and maintaining aids to navigation and user equipment required for national defense. DOT is the primary Government provider of aids to navigation used by the civil sector, and of certain systems used by the military. On April 17, 1979, an interagency agreement became effective requiring coordination between these two agencies for navigational planning.

Within DOT, the Coast Guard has statutory responsibility for defining the need for and providing aids to navigation and facilities needed for safe and efficient navigation. The Coast Guard may establish, maintain, and operate: aids to maritime navigation required to serve the armed forces and the commerce of the United States; aid to air navigation required for the armed forces peculiar to warfare and primarily of military concern; and electronic aids to navigation systems required to serve the armed forces peculiar to warfare or primarily of military concern, to serve the needs of maritime commerce, or to serve the needs of air commerce as required by the Administrator of the Federal Aviation Administration (FAA). The FAA, which is also part of DOT, is responsible for developing and implementing radionavigation systems for all civil and military aviation, except for those needs of the military which are peculiar to air warfare and primarily of military concern. FAA also is responsible for operating aids to air navigation required by international treaties. The St. Lawrence Seaway Development Corporation has responsibility for assuring safe navigation along the seaway.

The Department of Commerce, through the National Oceanic and Atmospheric Administration, provides charts and related information for the safe navigation of marine and air commerce. DOC also performs research related to the propagation of radio waves, including factors which affect the accuracy of radionavigation systems. Through the U.S. Maritime Administration, DOC is also responsible for promoting the interests of the U.S. Merchant Marine, including equipping ships with the best possible navigation aids.[35]

---

[34] Although the plan is dated July 1980, it was not formally transmitted to Congress until Jan. 6, 1981.

[35] This reference to the Maritime Administration being in the DOC is from the FRP, but it should be noted that Marad was transferred to DOT in August 1981 (Public Law 97-31).

NASA supports navigation by developing technologies for navigating aircraft and spacecraft, and develops ground-based equipment and user equipment. In the Navstar program, for example, NASA is responsible for developing low-cost user sets for use by the general aviation community. NASA is also authorized to demonstrate the capability of military navigation satellite systems for civil users.

b. *Significance of cost to civilian users.*—One of the most critical factors in determining how widespread civil use of Navstar will be is the cost of the receivers. In 1980, Loren E. DeGroot of Rockwell/Collins (one of the manufacturers of user sets) reportedly estimated the cost of an airline-type user set at $20,000–$25,000.[36]

For smaller aircraft, such as those used by the general aviation community, NASA is attempting to develop sets that will cost as little as $2,500 (in fiscal year 1978 dollars).[37]

The cost issue is of great importance to civil users, while for military users, a more critical issue is system performance under times of crisis. This is one of the difficulties inherent in developing systems which will be used by both communities. The FRP points out that the degree of Navstar's acceptance by the civil community "will be especially sensitive to the successful design of low-cost user equipment."[38]

The cost issue is also involved in the decision on what existing systems to phase out once Navstar is operational (discussed earlier). For example, the FRP states that:

> Without adequate analysis, one could conclude, superficially, that the "optimal" policy would concentrate Government investment in a single future radionavigation system to meet all user requirements. Such a conclusion, however, neglects the significant user investment in existing systems and other economic aspects which require a careful analysis of costs and benefits.

* * * * * * *

> Direct costs to the Government, as the operator of radionavigational services, and to the user, who must buy the equipment needed to use the service, must be carefully analyzed. The analysis of these costs must consider initial investment; operating, maintenance and replacement costs; and the unamortized capital investment remaining at the time that replacement of the system is contemplated. In the civil sector, the cost of user equipment more than any other single factor, influences the acceptability of a new system by the majority of civil users. Substantial unamortized investment in user equipment for an older system will cause strong resistance to replacement.[39]

As noted earlier, a cost/benefit analysis of various navigational systems is planned to be completed in 1982.

c. *International issues.*—The FRP identified three international issues that will have to be considered when deciding on future U.S. navigational aids.

First, at the present time foreign countries are able to access U.S. navigational aids without charge. A review of whether to charge for this "incidental" use of U.S. systems is now being conducted. Second, there are international standards as to what navigational systems will be used. For aviation, these standards are established by the International Civil Aviation Organization. The Inter-Governmental Maritime Consultative Organization might be involved in choosing international standard navigation systems for maritime uses. NATO is also a user of U.S. systems and would probably have to be consulted on any major changes in system availability (NATO is a participant in the Navstar Joint Program Office). Any U.S. decision on changing navigation systems would have to take these international ramifications into account.

---

[36] Philip J. Klass. "Civil Use of Global Positioning System Studied." Aviation Week and Space Technology, May 5, 1980. p. 74.

[37] U.S. Congress. Senate. Committee on Commerce, Science, and Transportation. NASA Authorization for Fiscal Year 1980. Part 3. Hearings, 96th Congress, 1st session. Mar. 2, 14, 15, May 1, and June 4, 1979. Washington, U.S. Government Printing Office, 1979. p. 1567.

[38] U.S. Department of Defense and Department of Transportation. Federal Radionavigation Plan. Vol. 1. Springfield, Va., National Technical Information Service, July 1980 DOD-No. 4650.4-P.1/DOT-TSC-RSPA-80-16, 1. p. I-59.

[39] Ibid., p. I-67.

A third international issue concerns technology transfer. The FRP states that permitting other countries to manufacture and sell user equipment competitively would be an important factor in achieving international acceptability of a system such as Navstar,[40] but this would have to be weighed against concerns related to technology giveaway which have received increased prominence in the Reagan administration.

4. *Who should operate navigation systems in the United States?*

An issue that remains unresolved is what Federal agency should operate U.S. navigation systems. In addition to the problems civil users have in using military systems (such as the fact that the military reserves the right to turn off satellites without warning to civil users), there is an international component which must be considered. When the space age began in the late 1950's, the U.S. space program was split into military and civilian sectors specifically so that other countries would feel free to cooperate with the U.S. civilian side of the program, even though in general the military program was not accessible to them. The FRP stated that the fact that Navstar is a military system may mitigate against other countries being willing to use the system. This factor has not apparently had a significant effect on international use of Transit, however.

There have been suggestions that once a system like Navstar is available to the civil sector, operational authority be transferred to a civilian agency such as the Department of Transportation.

Another possibility is to create an international agency like Intelsat or Inmarsat (see chapter 3) to handle navigation systems. This option might still require changes to existing U.S. Government structure for navigation systems.

One problem in choosing a civilian agency to operate the satellite systems is the possibility that it would be difficult to amalgamate new systems into the existing network. For example, a September 1981 study by the General Accounting Office charged that despite recommendations that Navstar could replace many existing systems, DOT had continued to develop, expand, and improve navigation systems which GAO thought could be discontinued. The agency also found that DOT had made little effort to evaluate Navstar's potential as a marine and land navigation system, and had not "initiated a program to develop and demonstrate the technology necessary to ensure the availability of low-cost receivers for marine and land users." [41]

---

[40] Ibid., p. I-69.

Thus, it might be difficult to introduce new systems if the responsible agency is reluctant to give up older systems. These issues have not been addressed in depth at this time, but are likely to receive increasing importance as the Navstar program proceeds, and as DOD and DOT ready their 1986 recommendation on future U.S. navigation systems.

---

[41] U.S. General Accounting Office. "DOT Should Terminate Further Loran-C Development and Modernization and Exploit the Potential of the Navstar/Global Positioning System;" report to the Secretary of Transportation. Washington, U.S. GAO, Sept. 18, 1981. MASAD-81-42. p. 1.

CHAPTER NINE

TRACKING AND DATA RELAY SATELLITE SYSTEM

I. INTRODUCTION

The National Aeronautics and Space Administration [NASA] will lease the services of a Tracking and Data Relay Satellite System [TDRSS] scheduled to begin full operation in 1984. TDRSS will consist of communications satellites in geosynchronous orbit and a ground station at White Sands, New Mexico to relay voice and data transmission between low Earth-orbital spacecraft and mission control. The system is being provided to NASA under a contract with Space Communications, Co. [Spacecom] during the period 1983–93. (For a schedule of launch dates, see table 9-1.)

TABLE 9-1*

TDRSS Schedule

TDRSS Network Ground System (NCC, NASCOM, NGT, WSGT, OSCF) Operational	June 1982
TDRS-A Launch (F1)	January 1983
TDRS-B Launch (F2)	September 1983
TDRS-C Launch (F3)	January 1984
TDRSS Network Operational (two operational and one spare in orbit)	May 1984
TDRS-D Launch (F4) (Advanced Westar)	July 1984

---

* Dates were supplied by NASA and are current as of December 1981.

NASA Earth-orbital spacecraft are presently monitored by the Spaceflight Tracking and Data Network [STDN] managed by the Goddard Space Flight Center. After TDRSS becomes operational, NASA plans to close 9 of its 13 ground stations and to consolidate the remaining stations with the Deep Space Network [DSN] which tracks planetary spacecraft. The remaining STDN stations are required for spacecraft in highly elliptical Earth orbits and launch support. (See volume 1, chapter 4.)

TDRSS has the capability to provide greater than 85 percent coverage of low orbiting satellites in orbit when fully operational compared to STDN's capability of about 15 percent coverage. The system will allow NASA to provide greater support for the user spacecraft community, and at the same time will eliminate the complexity, expense and inefficiency of the large network of STDN ground stations.

The TDRSS system is the first large-scale joint venture between NASA and a commercial company where the objectives of each organization are combined into a shared satellite system. Both the shared spacecraft concept and NASA's lease rather then purchase rationale used in acquiring the system made the TDRSS program an especially unique one. It was initially hoped that TDRSS could serve as a model for future Government acquisition of satellite services. Difficulties encountered throughout the 7-year history of the program have brought into question the viability of such arrangements with the private sector.

Originally scheduled to be operational in 1980, TDRSS has been delayed as the result of various technical problems, debate over contractual agreements, and the slippage of the space shuttle, which is designated to launch all TDRS hardware.

II. SYSTEM DESCRIPTION [1]

The TDRS system will consist of an operational constellation of four spacecraft in geosynchronous orbit, a ground terminal at White Sands, N. Mex. [WSGT], and scheduling and communication facilities at the Goddard Space Flight Center [GSFC] in Greenbelt, Md.

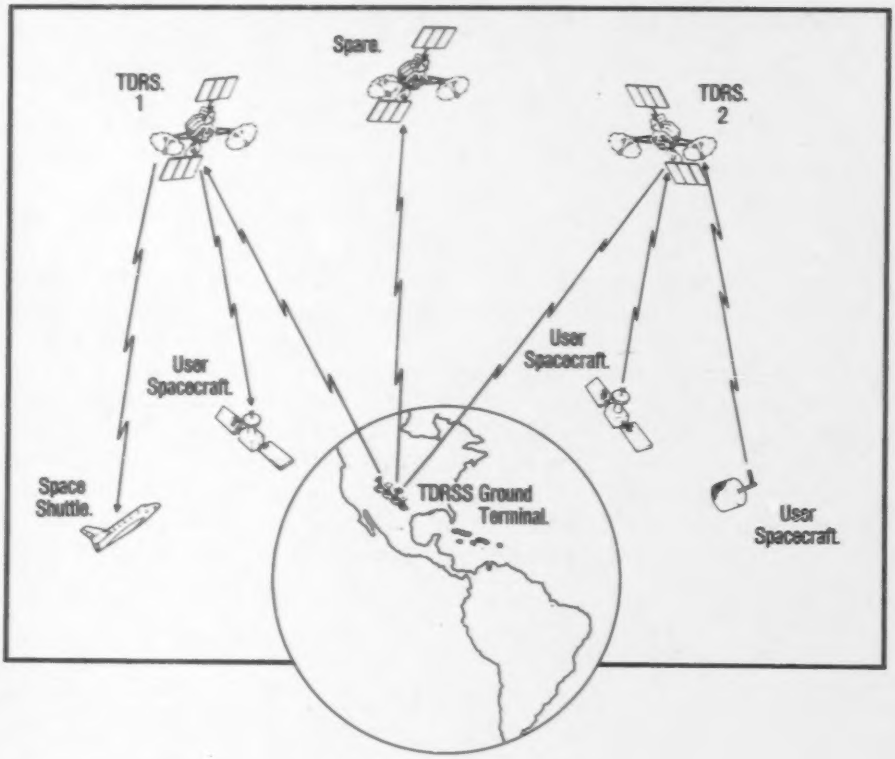
Two of the spacecraft will service NASA: One over the mid-Atlantic at 41 degrees west longitude (east satellite); the other over the mid-Pacific at 171 degrees west longitude (west satellite). Positioned between these units will be an Advanced Westar satellite which will provide commercial service as a domestic communications satellite and a spare (at 79 degrees west longitude) for the maintenance of both services. (See figure 9-1) All satellites are built with a design life of 10 years.

---

[1] This section is based on: Sade, Richard S. and Leonard Deerkoski. "Tracking and Data Relay Satellite Operations in the 1980's"; and Smylie, Robert E. "NASA Activities and Plans." Published in Space Tracking and Data Systems. Proceedings of the American Institute of Aeronautics and Astronautics/National Aeronautics and Space Administration Symposium on Space Tracking and Data Systems, June 16–18, 1981, Pentagon City, Va.; New York, AIAA, 1981. pp. 65–70, 77–87.

FIGURE 9-1

Tracking and Data Relay Satellite System.


Spare.
TDRS. 1
TDRS. 2
User Spacecraft.
User Spacecraft.
Space Shuttle.
TDRSS Ground Terminal.
User Spacecraft.

Source: Spacecom.

SPACECOM™
SPACE COMMUNICATIONS COMPANY

The east and west satellites, to be used by NASA only, will provide full coverage for satellites in orbits higher than 1,200 kilometers with at least 85 percent coverage for satellites in lower orbits. The location of the two NASA TDRSS satellites gives each one a wide coverage area unblocked by Earth's horizons. The two-satellite system has the capability to serve 24 spacecraft simultaneously and to support a user community of 100.

The TDRS system (including the spare) can provide data relay service for up to 26 users at the same time with data rates ranging from 100 bits per second (bps) to 300 megabits per second (Mbps) plus accurate tracking data for user orbit determination. Communications between the TDRS and users will be at frequencies in the S- or K-band [2] depending on specific data rates and requirements.

K-band antennas at WSGT allow command, telemetry and tracking for each satellite along with the total uplink and downlink activity with user spacecraft. Launch and emergency control of all TDRS is provided by S-band tracking, telemetry and command [TT&C] antenna placed in such a position that it possesses the greatest unblocked field in the group of antennas.

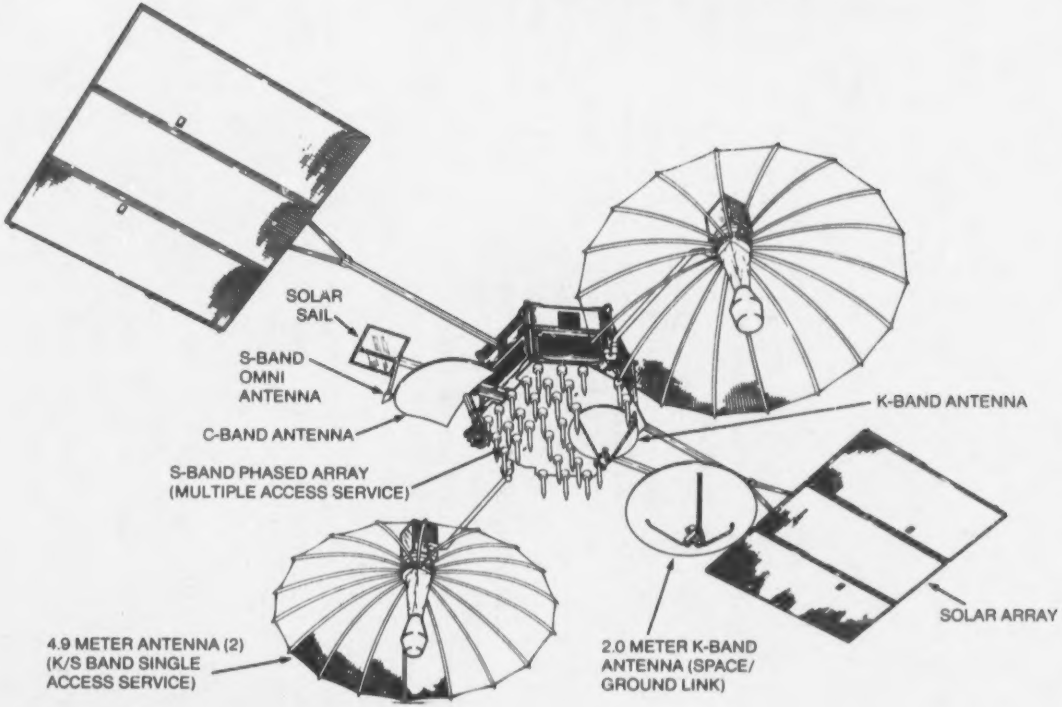
Each TDRS is solar-powered and will have two high gain 4.9 meter parabolic antennas, each with potential S-band or K-band service to a spacecraft (see figure 9–2). There is also an electronically steerable phased array antenna, known as the multiple access system, which can communicate with as many as 20 low data rate users simultaneously. Operating at S-band, the multiple access limits each user to a data rate of 50 kilobits per second (Kbs). The single access antenna can go as high as 300 Mbs per second at K-band.

---

[2] S-band frequencies are in the 2- to 2.3 GHz range; K-band frequencies are in the 13.4 to 15.2 GHz range.

FIGURE 9–2

TRACKING & DATA RELAY SATELLITE (TDRS)


SOLAR SAIL
S-BAND OMNI ANTENNA
C-BAND ANTENNA
S-BAND PHASED ARRAY (MULTIPLE ACCESS SERVICE)
K-BAND ANTENNA
SOLAR ARRAY
4.9 METER ANTENNA (2) (K/S BAND SINGLE ACCESS SERVICE)
2.0 METER K-BAND ANTENNA (SPACE/ GROUND LINK)

Source: Spacecom.

The single interface point for TDRSS is the ground terminal at White Sands, New Mexico. The WSGT location is advantageous because the dry climate will not limit the use of the K-band uplink and downlink. Also, the WSGT is at a longitude that provides a clear line-of-site to east and west TDRS permitting the interrupted coverage area to fall over the Indian Ocean. WSGT houses all the antennas and equipment necessary to transmit and receive data through TDRS.

In addition to its ground and space segments being provided through the Spacecom contract, the TDRS operational support system includes six other elements in its operations. The NASA Ground Terminal [NGT] will be colocated with the WSGT to provide the interface between the leased TDRSS and the NASA owned portion of the system. The Bilateration Ranging Transponder System [BRTS] will consist of five ground-based transponders transmitting signals from ground reference points for accurately pinpointing TDRS positions. The Network Control Center [NCC], located at GSFC, will be the focal point for NASA operations with the TDRS and other network elements. The Operations Support Computing Facility [OSCF], also located at GSFC, will provide the network with orbital predictions and definitive orbit calculations for user spacecraft and TDRS. The NASA Communications Network [Nascom] will function as the common carrier interface at network locations.[3] Finally, the relay located with the Merritt Island STDN Station provides an interface between a spacecraft and the TDRS for prelaunch check-out.

All TDRS's will be launched by the space shuttle and will be carried into geosynchronous orbit by the Inertial Upper State [IUS]. The shuttle will be controlled from JSC, the IUS from the U.S. Air Force Control Center at Sunnyvale, Calif., and the TDRS from White Sands.

The TDRS, exclusive of the NASA portions of the ground support system, is being developed to NASA service requirements by an industry team headed by Spacecom. Spacecom is jointly owned by Western Union Corp., Fairchild Industries, and Continental Telephone Co. TRW Defense and Space System Group,[4] and Harris Government Communications Systems Division are the two prime subcontractors under Spacecom for spacecraft, ground terminal equipment, and software.

III. PROGRAM HISTORY

A. Lease Versus Purchase Decision

Congress was approached by NASA in October 1973 with an outline for a Tracking and Data Relay Satellite System [TDRSS]. At that time, the possibility for a leased system was only one of several alternatives being considered by NASA for financing the project.

In January 1974, a full analysis of TDRSS was presented to congressional committees by NASA's Office of Tracking and Data Acquisition (OTDA, later renamed the Office of Space Tracking and

---

[3] See vol. 1, p. 121 for discussion of NASCOM.

[4] In December 1981, TRW reorganized and the TDRSS program became part of the new TRW Electronics and Defense Sector.

Data Systems).[5] OTDA recommended that TDRSS be procured on a leased system basis whereby a contractor could either provide service dedicated to NASA or incorporate such capabilities in a spacecraft system shared with other services, but TDRSS design would reflect NASA studies. NASA planned a 10-year leasing period in which the contractor would operate both the space and ground segments.

NASA's decision to acquire TDRSS through a lease contract was predicated, in part, on the fact that the economic cost to lease TDRSS was not estimated to be significantly different, than to purchase it.[6]

According to NASA testimony,[7] the lease approach would have allowed them to:

Circumvent to NASA budget crunch;

Prevent penalties to other NASA program funding;

Avoid fiscal outlays before the 1978/79 time period;

Allow a single lease contract for the spacecraft, terminals and operations;

Let spacecraft and terminal risks be assumed by the contractor;

Allow a pre-determined level of operations funding over a ten-year period, thereby preventing balloon payments associated with cost overruns;

Waive a lease/purchase agreement;

Conform to NASA policy for purchase of communication services;

Conform to national policy as promulgated by the Office of Telecommunications Policy of encouraging reliance on the private sector this area of federal telecommunications;

Implement a system serving as an example of the movement of space research and development into applications by the private sector.

The disadvantages of a TDRSS lease approach included in the NASA analysis were as follows:

Launch risks and costs might have to be borne by NASA;

The approach might require channel or spaceraft sharing by the contractor;

NASA might not be allowed the technical flexibility once the contract is executed with the private sector;

A new method of program monitoring might have to be undertaken; otherwise, theoretically at least, the successful bidder would be left alone until delivery of the system for launch by NASA;

The contractor costs (to be written off by the annual lease fee) could possibly escalate as a result of "out of scope" changes requested by NASA subsequent to the award;

---

[5] U.S. Congress. House. Committee on Science and Astronautics. Subcommittee on Aeronautics and Space Technology. Review of Tracking and Data Acquisition Program. 93d Congress, 2d session, Jan. 29, 1974. Washington, U.S. Government Printing Office, 1974. p. 279-80.

[6] U.S. General Accounting Office. "Methodology Used In Lease-Versus-Purchase Decision for Tracking and Data Relay Satellite System." Report to the Congress by the Comptroller General. Washington, USGAO, July 15, 1976. LCD-76-127.

[7] U.S. Congress. House, Committee on Science and Astronautics. Subcommittee on Aeronautics and Space Technology. Review of Tracking and Acquisition Program. 93d Congress, 2d session, op. cit.

NASA will incur a contingent liability upon the award date and this liability (if for some reason NASA decided to terminate the contract for the convenience of the Government) would continue to grow until the services are actually provided;

NASA would not have title to any hardware and/or facilities (unless Government facilities are used). These would remain vested in the private concern when the lease period expired or the program was terminated;

The property rights in inventions resulting from the TDRSS development would have to be determined;

The total costs to NASA for TDRSS, although deferred, would probably be more than the cost associated with a standard NASA procurement of this type, although shared system rates may prove to be more favorable.

Both House and Senate committee members expressed concern over NASA's proposal to lease rather than buy a TDRS system. They were not convinced that leasing would be less expensive than purchase of the system. The Senate Committee on Aeronautical and Space Sciences adopted a provision approved by the House to require congressional review before a leasing contract was awarded.[8]

NASA conducted extensive economic cost/benefit analyses for both the leased and NASA-owned services. Both yielded favorable ratios of economic benefits to costs; the leased service yielded 1.30, the NASA-owned service yielded 1.58.[9]

From NASA's view, the main differences between the two procurement alternatives, aside from TDRSS ownership, were the timing of expenditures and the total cost.[10] With a purchased TDRSS, NASA would have made substantial outlays during the TDRSS development phase (1977-79) concomitant with development of the space shuttle. With a leased TDRSS, NASA could make monthly lease payments to the prime contractor beginning in 1980 when TDRSS was expected to be operational. However, in absolute dollars, a leased TDRSS required substantially higher outlays than a system NASA would own because of the higher return on investment to be paid to the contractor for financing TDRSS development and for assuming increased risk in providing the communications service.

Section 6 of the NASA Authorization Act for 1978 allowed NASA to enter into and maintain a contract for TDRSS. It differed from the fiscal year 1975 provision in that it provided for permanent authority remaining in effect unless repealed by legislation enacted by Congress.[11]

---

[8] U.S. Congress, Senate. Committee on Aeronautical and Space Sciences. NASA Auhorization for Fiscal Year 1975. 93d Congress, 2d session, Apr. 2, 1974, Washington, U.S. Government Printing Office, 1974. pp. 1085-86.

[9] Ibid.

[10] U.S. General Accounting Office. "Methodology Used In Lease-Versus-Purchase Decision For Tracking and Data Relay Satellite System," op. cit.

[11] The 1978 NASA Authorization Act (Public Law 95-76a) gave NASA the necessary authority to enter into the TDRSS lease arrangement.

1. 1976 GAO Review

In 1976, GAO released a report entitled: Methodology Used In Lease-Versus-Purchase Decisions For Tracking And Data Relay Satellite System.[12] The purpose of the GAO review was to determine the validity of the methodology used by NASA to compare lease and purchase alternatives for acquiring TDRSS, as requested by Senator Frank E. Moss of the Senate Committee on Aeronautical and Space Sciences and Congressman John W. Wydler, of the Subcommittee on Aeronautical and Space Sciences of the House Committee on Science and Technology.

The report was released at the same time NASA was evaluating cost proposal data from two bidders: Western Union Telegraph Co. and RCA Globcom Communications Inc. Both companies had been selected by NASA to prepare a lease proposal for TDRSS.

GAO concluded that NASA analyses leading to the decision to lease rather than purchase TDRSS used an acceptable method of making such comparisons. GAO also found that the cost categories defined by NASA for both alternatives seemed to be complete and the NASA applied a widely used and accepted technique—conversion of present value—in timing of lease vs. purchase costs.

Using 1976 contractor proposal-cost data in 1974 dollars, the report showed a 1980-90 leased system cost of $752.9 million compared to $480.2 million for a NASA-owned TDRSS. Those numbers, less the recovery costs through Federal income tax ($113.1 million in recovery for a leased system and $24 million for a NASA-owned system) brought the estimates down to $639.8 million to lease and $462.2 million to buy. A 10 percent discount rate was used in converting future costs to present value, bringing the final estimates to $249.6 million for a lease system and $245.2 for an owned one (a difference of $4.4 million). However, the study also showed that the use of an 8.25 percent discount rate resulted in a significant difference—making it $22.6 million more expensive to lease than to buy.

In accordance with the instructions from its requestors, the report did not assess the accuracy of cost estimates used in NASA analyses, nor did it examine the detailed procedures and applications of NASA's methodologies to specific cost.

2. Original Contract

NASA awarded the TDRSS contract in December 1976.[13] A new, wholly-owned subsidiary of Western Union Corp. called Western Union Space Communications Inc., was chosen over General Electric (which replaced RCA Globcom as prime contrator) for the contract, after each had presented proposals for the system.

The terms of the original TDRSS contract provided for 10 years of TDRSS service to begin when the system was accepted as operational by NASA, at that time scheduled for December 31, 1979. The contract had a fixed price of $786 million, with an additional maximum award fee of $10 million, for a total of $796 million or approximately $80 million annually, subject to adjustment for changes to planned labor rates, material costs and interest rates as a result of economic fluctuations.

---

[12] U.S. General Accounting Office. "Methodology Used In Lease-Versus-Purchase Decision For Tracking and Data Relay Satellite System." Op. cit.

[13] National Aeronautics and Space Administration. Contract with Western Union Space Communications, Inc., Dec. 22, 1976. NAS5-2500.

The contract specified a shared system utilizing four identical spacecraft in orbit: two operating NASA TDRS's, one in-orbit spare and one Advanced Westar satellite for domestic communication use by Western Union. Two spares would also be kept on the ground in case of a failure in any spacecaft, making a total of six satellites to maintain the constellation over 10 years. The first three spacecraft were to be financed by Western Union and launched by Atlas Centaur launch vehicles, the next three by the space shuttle and the Solid Spinning Upper Stage [SSUS], paid for by NASA. Cost of the Advanced Westar portion of the system was to be borne by the contractor.

The Federal Financing Bank [FFB) made loans guaranteed by NASA, to the contractor, to finance the project. When lease payments began, NASA would also have to make principal and interest payments on the FFB loan. The contract was to be adjusted for variations in interest fluctuations from the 7.5 percent contract baseline rate. Adjustment for variations in actual launch vehicle costs, actual costs of State and local taxes, and for inflation above 5.5 percent or below 4.5 percent for part of the labor and material, were also included in the contract.

It was agreed that Western Union would hold title to the spacecraft and ground terminal at White Sands through the duration of the contract and that the Government would hold title to the launch vehicles and land used for the ground terminal. The Government had the right to acquire the leased TDRSS at any time by termination of the contract and payment of subsequent costs or at the end of the contract term by payment of $1.

B. 1979 Contract Modifications

The TDRSS program encountered a series of problems between 1976 and 1979. The most significant of these was a potential radio frequency interference problem that arose after the satellites had been designed and partially built, making the correction a costly one. Negotiations between NASA and Western Union on these and other disputes proceeded during most of 1978. A settlement was reached and the TDRSS contract was amended in February 1979.

1. Radio frequency interference [RFI]

It was discovered in 1978 that without satellite modifications, the east and west TDRSS satellites would be subject to radio frequency interference [RFI] that the trade press reported came from Soviet radars in Eastern Europe.[14]

The recovery time for the spacecraft's microwave integrated circuits, or the amount of time the spacecraft allows for entry of data, was at 100 milliseconds. This design characteristic would have allowed so much interference from Soviet radars that the spacecraft would not have been able to receive the intended data properly.[15]

---

[14] New TDRSS Problem: Spacecraft Modifications for RFI. Aerospace Daily, July 7, 1978. p. 15.

[15] "A $100 Million Satellite Error." Business Week, Aug. 7, 1978, p. 52.

RFI signals would not have affected data being relayed if dropout were to be reduced from 100 milliseconds to 1 microsecond. Providing for this contingency in the TDRSS design would not have been a problem, but since the satellites were in an advanced stage of construction when the problem was realized, remedying the mistake was not a simple task.

Technically, the RFI problem called for the installation of "limiters" that would have prevented the satellites from becoming overloaded with random noise put out by radar. This meant an overhaul of the instrument package to compensate for new weight and possible changes in heat distribution. The satellite then had to be retested for space readiness. NASA's original position [16] on the RFI concern was that Western Union was at fault and should be responsible for the total cost for necessary TDRS modifications and additions. NASA said they had been aware of the problem for some time and had made it clear to Western Union. The agency claimed their specifications had called for proper performance by the satellites.

Western Union, on the other hand, said they had been working to NASA specifications and NASA had failed to make the problem clear from the beginning. The company's premise was that if changes had to be made, NASA should take complete financial responsibility.[17]

Both sides considered settling the issue in court, but finally were able to enter into negotiations and reach an agreement without litigation. Western Union proposed $107 million for modifications; NASA agreed to pay $75 million.

NASA's final position on the matter stated that data containing information about the RFI environment was highly classified. In the process of requesting contract proposals, NASA identified the existence of RFI in a classified document included in the procurement package. For reasons of security, the subject was not included in the contract request for proposal, and there was nothing in the specifications detailing the RFI environment. The unclassified document was not sufficiently highlighted by NASA, and NASA's legal counsel concluded that the agency might be held liable for the entire cost of RFI modifications.[18]

2. Other contract modifications [19]

The Final TDRSS contract amendments added $80 million to NASA's bill. These modifications covered three fundamental areas.

First, an increase in spacecraft weight required by Western Union's Advanced Westar was taken care of by substituting the inertial upper stage [IUS] for the SSUS previously planned for the last three TDRSS launches. This gave NASA a $5-million credit because the change was made to satisfy commercial requirements.

---

[16] "New TDRSS Problem: Spacecraft Modifications for RFI." Aerospace Daily, op. cit.

[17] "A $100 Million Satellite Error." Business Week, op. cit.

[18] U.S. Congress. Senate. Committee on Commerce, Science, and Transportation. NASA authorization for fiscal year 1980. 96th Congress, 1st session, Feb. 28, 1979. Washington, U.S. Government Printing Office, 1979. p. 1265.

[19] U.S. Congress. Senate. Committee on Commerce, Science, and Transportation. NASA authorization for fiscal year 1980. 96th Congress, 1st session, Feb. 28, 1979. Washington, U.S. Government Printing Office, 1979. pp. 1264–65.

The next item was a provision allowing all TDRSS spacecraft to be launched on the shuttle/IUS. This change allowed a single design for all the spacecraft, incorporating reliability improvements and accommodating spacecraft weight increases which made launch via Atlas-Centaur undesirable. The decision necessitated a slip of 1 year, moving the first TDRSS launch date from December 1979 to December 1980. This change resulted in a net increase of $10 million.

NASA also included an agreement to launch a Western Union Westar C on a Delta launch vehicle in August 1979. This change developed because of a slip in the launch date for Landsat D, which originally had served as the deadline for having TDRSS operational. The slip negated a need for a launch back-up to the shuttle and NASA eliminated a requirement for a Titan/IUS when they decided to go to all shuttle launches. However, because of the shared system concept of TDRSS, Western Union needed to be sure commercial services were available, even if the shuttle slipped. NASA compromised by agreeing to launch their Westar C for commercial purposes.

Finally, the modifications required to correct the RFI problem were implemented and a cost settlement reached. The NASA cost increase was $75 million. The total TDRSS cost had risen to $876 million for the 10-year lease period.

C. SHUTTLE SLIPPAGE AND OTHER COST GROWTH

1. 1980

During hearings on its fiscal year 1981 budget request, NASA announced that TDRSS program cost would exceed $1.4 billion—$619 million more than the original contract price and $539 million higher than the settlement made a year earlier between NASA and Western Union.[20] NASA attributed more than one-third of the cost escalation—$225 million—to a delay in the shuttle schedule. The first TDRSS launch, scheduled for the first operational mission, had to be moved from December 1980 to March 1982.

Spacecom's[21] loan from the FFB, on which NASA had agreed to pay interest in the original contract, had to be revised each time the TDRSS program was delayed. The principal on the loan remained the same, but with every delay, the term of the loan was extended, since the borrowing period is dependent on the launch date. NASA officials estimated TDRSS costs were increasing $13 million per month of slippage at that time.[22]

Other factors contributing to TDRSS cost escalation were: economic factors, primarily inflation, $158.7 million; $104 million on contract changes ($24 million in assorted, unnegotiated contract changes added on to the 1979 settlement of $80 million brought the total increase to $104 million); $47 million for increased launch vehicle costs; $71.8 million for potential growth (money set aside for anticipated technical changes and award fees); and $22 million for program support.[23]

---

[20] U.S. Congress. Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Science, Technology and Space. NASA Authorization for fiscal year 1981. 96th Congress, 2d sess. on S. 2238 and S. 2240. Feb. 6, 1980. Washington, U.S. Government Printing Office, 1980. p. 942.

[21] Effective June 27, 1980, Fairchild Industries, Inc., and Continental Telephone Corp. each received 25 percent interest in Western Union's Space Communications, Inc. The agreement had no effect on NASA's contract with Spacecom for TDRSS.

[22] U.S. Congress. Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Science, Technology and Space. NASA Authorization for fiscal year 1981. Op. cit.

2. 1981

In 1981, NASA budget estimates reflected an even higher total cost for TDRSS—$1.8 billion for the 10-year service. This estimate was based on a September 1982 launch date for TDRSS/A. Most of the cost increase was attributed to interest build-up as a result of launch delays. Under the legislation that allowed NASA to enter into the TDRSS contract, payments on the FFB loan (including interest costs) cannot begin until the service had started.

In April, the TDRSS/A launch was delayed again from September 1982 to January 1983. TDRSS/A had been planned as the payload for the first operational shuttle mission because of the importance of telemetry coverage to later shuttle missions and free-flying satellites. However, the lightweight fuel tank, needed to launch TDRSS and the IUS, was not expected to be available until the shuttle's third operational mission; the shuttle was too heavy for TDRSS purposes without the lightweight tank.[24]

D. TDRSS SECURITY MODIFICATION

Another TDRSS schedule delay and cost escalation was threatened in 1981 when the Air Force decided to place a Batson II security system, at that time in development stages, on TDRSS. Batson II would have provided physical security against Soviet electronic signals interfering with the satellite orbits. DOD was preparing to place Batson II on all satellites supporting communications relay for the single integrated operations plan (SIOP), emergency action messages (EAMs), and critical worldwide military communications.

The application of Batson II to TDRSS would have meant another delay—slipping the launch of TDRSS/B from June 1983 to September 1983. This delay would have posed a problem for TDRSS support of the European Space Agency's first spacelab flight, then scheduled for September 1983. The spacelab mission needed both the east and west TDRSS satellites in position for recycling experimental data to the ground. TDRSS/B had to be launched at least 3 to 4 months before spacelab was launched on the shuttle to allow time to check out the system. The encryption modifications would have delayed the spacelab flight until at least January 1984.

Spacecom, prime contractor for TDRSS, estimated the cost for Batson II modifications for all six spacecraft at between $314 million and $500 million. NASA expected DOD reimbursement for the modifications and related program support costs since the added equipment was a DOD requirement.

In light of the cost impact, the Air Force decided in June 1981 to cancel plans for implementation of Batson II on TDRSS. The precise reasons why the Air Force decided the risk of electronic interference did not justify the cost of the security program have not been revealed.[25]

---

[23] Ibid.

[24] TDRSS Delay. Aerospace Daily, Apr. 6, 1981. p. 202.

E. Inspector General Report 1981

In March 1981 NASA released an audit report by the agency's Office of the Inspector General (IG) on the Tracking and Data Relay Satellite System.[26] The review primarily addressed cost increases in the program which were chiefly the result of complex financing arrangements and technical changes. Other areas of emphasis in the audit included: Planning; enabling legislation; NASA's original lease versus purchase analysis; difficulty in acquiring private capital; contract administration; and project management. The areas were highlighted in the report because they deviated from conventional methods used by NASA in its acquisition, financing, and managing of space programs.

According to the report, NASA's share of the TDRSS program cost was estimated to be $2.156 billion. This figure consisted of $1.985 billion for contract costs and $171 million for shuttle launches--resulting in a 150-percent increase in the estimated contract price.

The biggest contributor to be increased TDRSS costs was interest on the 10 year loan from the FFB. Total interest cost escalated to $689 million—an increase of $169 million since the contract was signed in 1976. The IG report said the FFB loan was made with little or no risk to the contractor and no risk to the lender (FFB). It became a loan made by the Government (FFB), guaranteed by the Government (NASA), to be repaid by the Government (NASA). Interest costs for 1980 alone were estimated at $100 million.

Delays in the TDRSS design and development were aggravated, according to the IG, by the fixed-price nature of the contract with Spacecom. Under such a contract, NASA's in-house experts were not required or permitted to become actively involved in the ongoing mainstream of TDRSS technology development. This led to major design/cost tradeoffs which ultimtely resulted in increased costs.

The report concluded that the procurement procedure had been irregular. Only two contractors responded to the phase I design contract, mainly because eligible contractors had to demonstrate their capability to assume full responsibility for financing, developing, delivering, operating, and maintaining a TDRS System over the entire period of the contract. However, according to the IG report, the phase I design contract was let to both Western Union and RCA Globcom before either had demonstrated the capability to assume the required financial responsibility. In addition, only the contractors eligible for phase I were able to bid on phase II—construction of TDRSS. Then in June 1976, NASA shifted the financing responsibility from the contractor to the Government, eliminating the need for the chosen contractor—Western Union—to show financial ability to carry out the project.[27]

---

[25] Air Force TDRSS Decision. Aerospace Daily, June 22, 1981. p. 282.

[26] This section is based on: National Aeronautics and Space Administration. Office of the Inspector General. Audit Report on the Tracking and Data Relay Satellite System. Washington, NASA, Mar. 20, 1981. A-A-80-007.

Specific recommendations related to these and other findings were set forth in the report and included recommendations that:

> NASA strengthened its management controls and oversight in the planning and management system to achieve a better definition and understanding of the total TDRSS program through more complete and realistic technology and capability assessment and assure program changes receive appropriate management attention.
>
> The Associate Administrator for Space Tracking and Data Systems arrange for, or have completed at an early date, a current and complete exploration and reassessment of the TDRSS program with a view toward identifying the various alternatives that may be available to: (1) complete the acquisition (including the launching) of TDRSS on a more prudent business basis, and (2) minimize the agency's vulnerability and enhance its opportunity for a successful and timely acquisition of a system to meet its need—identifying potential dollar savings with various alternatives including opportunities for savings resulting from reduced financing costs through a liquidation or restructuring of the current 10-year lease financial arrangement.
>
> NASA, upon completion of this reassessment, arranged for a comprehensive presentation to OMB and appropriate congressional committees/subcommittees, and solicit their aid in selecting an alternative which would be in the best interest of the Govenment.[28]

At the time the report was published, matters concerning RFI, Economic Price Adjustments and a $2.78 million overpayment to Western Union remained under investigation.

---

[27] NASA Audit of TDRSS Attacks Faulty Financing as Cause of $1.2 Billion Budget Overrun. Satellite News, June 1, 1981. p. 3.

[28] National Aeronautics and Space Administration, Office of the Inspector General. Op. cit.

○